.3

CONSEIL PERMANENT INTERNATIONAL
POUR L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT – DANEMARK

JOURNAL DU CONSEIL

VOL. XVI · NO. 3

PUBLIÉ PAR LE BUREAU DU CONSEIL

RÉDIGÉ PAR
J. R. LUMBY

LIBRARY
FISH & WILDLIFE SERVICE
PACIFIC OCEANIC FISHERY
INVESTIGATIONS
AUG 31 1950

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

JUILLET 1950

Notice.

The Journal of the Council appears *three times a year*, and three numbers form a volume. It includes, in addition to general articles, reviews, and bibliography, the special papers previously issued in the series of *Publications de Circonstance.*

The subscription price is 16 Kroner (+ mailing expenses) a volume, which includes, if desired, a reprint of the bibliographical matter, printed on one side of the paper. Single copies are sold at Kr. 6.00.

Orders for copies should be sent to Messrs. **Andr. Fred. Høst & Søn, Bredgade, Copenhagen.**

Correspondence, books and papers for review or bibliographical notice, and all contributions to the Journal, should be addressed to the **Editor, Journal du Conseil, Fisheries Laboratory, Lowestoft, England.**

CONSEIL PERMANENT INTERNATIONAL
POUR L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT – DANEMARK

JOURNAL DU CONSEIL

VOL. XVI · NO. 3

PUBLIÉ PAR LE BUREAU DU CONSEIL

RÉDIGÉ PAR
J. R. LUMBY

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

JUILLET 1950

On the Cartographical Method for Studies of the Ice off the Finnish Coast.

By

Risto Jurva.

A study of the ice conditions in the seas bordering on Finland is made difficult by the wide variations which occur both in time and in extent of the ice cover. For example, a certain situation in the general course of the ice winter may occur within a time interval of two or even three months. On the other hand, in some winters the freezing, even at its height, may not cover more than the innermost parts of the Gulf of Finland, as was the case in the winters 1929—30 and 1938—39; in others it may reach over the entire Baltic and Kattegat, and even far into the Skagerak, as, for instance, in the winter 1939—40.

For this reason the "general" course of the ice winter could not be determined by the usual, so-called numerical method, and we were obliged to develop a new, *cartographical* method for this purpose.

Before this method is explained it is necessary to describe briefly the ice situations which occur in the seas bordering on Finland.

Figure 1 shows a typical ice situation and represents the ice conditions for 22. January 1926. Short, thin lines indicate open sea; the crosses, thin ice or blue ice; the lines running out from the coast and ending usually at the border curve indicate the *coastal border of fast ice;* the triangles denote drift ice, and the circles pack ice; the black triangles and circles solid drift and pack ice respectively, and the short broken lines the banks of pack ice.

The date of the chart representing the ice conditions, the coastal border of fast ice, the areas of solid and immobile ice, and of loose ice, the area or areas of open sea, and, finally, the thickness of the ice (and snow) are the five elements with which one may define an ice situation. The determination of the average course of these five elements and the extent of their variations enable us to comprehend the ice conditions in the Finnish part of the Baltic and adjacent gulfs.

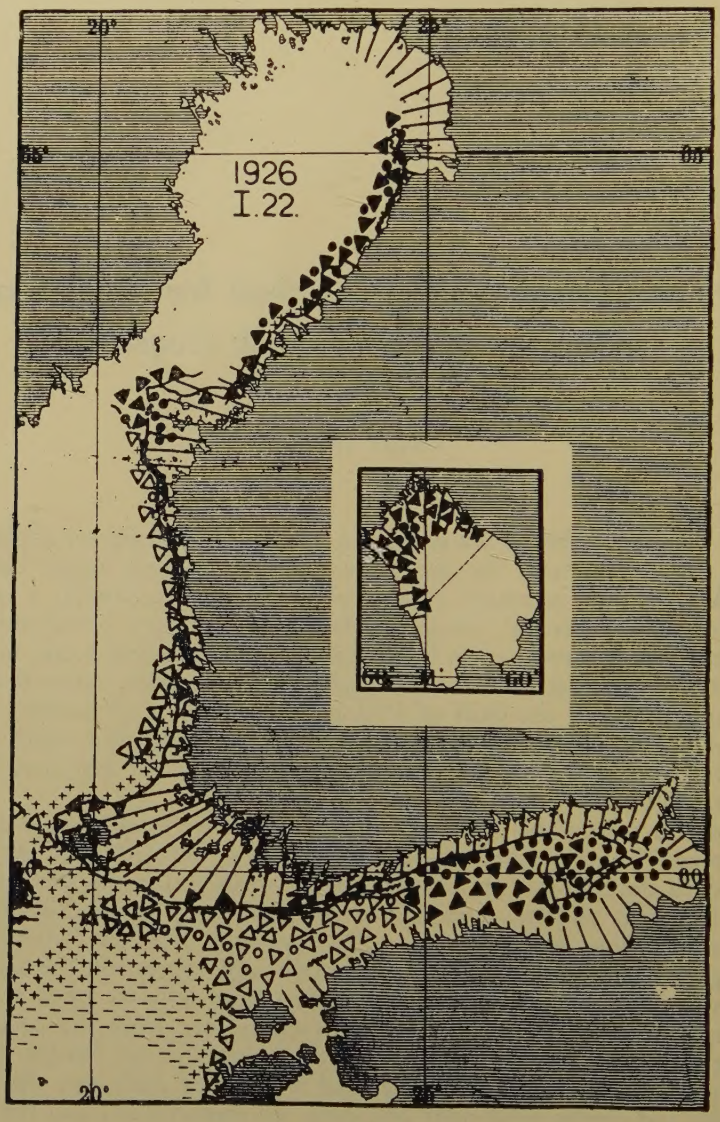


Figure 1.

A chart of the ice conditions contains such a great number of facts that a verbal presentation of even the main features is very difficult to make and it would, moreover, be impossible to convey in this manner both a general idea of the ice conditions and a sufficiently clear conception of the details. As mentioned, the general course of the ice winter cannot be defined according to the usual method. A new

method has therefore been developed which enables one to preserve a very large number of facts, including the structural characteristics of the ice conditions.

In order to place the various ice winters on a comparable basis, in spite of the great variations in time and extent, and to express these variations in figures, the first step was to determine the comparison or normal winter.

The normal winter represents and repeats all the variations of the winters in regard to both time and extent of freezing and, moreover, gives a conception of the character of the ice conditions, i. e., of the structure of the ice situation. The different points or stages in the general course of the normal winter must therefore correspond to those average situations which contain all the elements of the ice situations. Because the freezing at any one time may vary from winter to winter within very wide limits, it is self-evident that the stages of the normal winter cannot be determined from the ice situations relating to a particular date, but they must be deduced from ice situations which are as similar as possible, irrespective of the date of their appearance in different winters. The criterion for "similarity" is that situations are regarded as similar only if the ice cover is increasing in all of them, or, conversely, if it is decreasing. In other words, the stages in the general course of the normal or comparison winter must be determined in such a way that the course of the ice winter is at first detached from time. Thereafter the situations corresponding to, and thus representing, the same point in the general course of the winter can be determined. From these situations an ideal ice situation has been deduced, which forms the stage in the general course of the ice winter that corresponds to the ice situations during the different winters used to determine this stage.

The main criterion for the similarity of the ice situations is their most lasting feature, the fast ice border. The arrangement of the ice situations according to the state of the fast ice border (separated into occasions of increasing and decreasing ice) is given in Figure 2, which relates to the Gulf of Finland.

In those parts of the diagram denoted by "*ml*", "*l*" and "*k*", the numbers 1, 2, 3, etc. indicate the ice situations considered, according to the state of the border of fast ice. They also show to which group of similar ice situations they belong and they correspond therefore to the points 1, 2, 3, etc. in the general course of the winter. Diagram "*ml*" shows the arrangement of the entire material for ice situations in groups from which the points or stages of the standard *medium long* and *medium severe winter* are determined. The part of the diagram marked "*k*" illustrates the deduction of the stages for a short normal winter from the situations for different winters, and the part "*l*" shows the same process for a long winter.

When all the ice situations had been allocated to the different groups, the limits for the border of fast ice corresponding to a certain

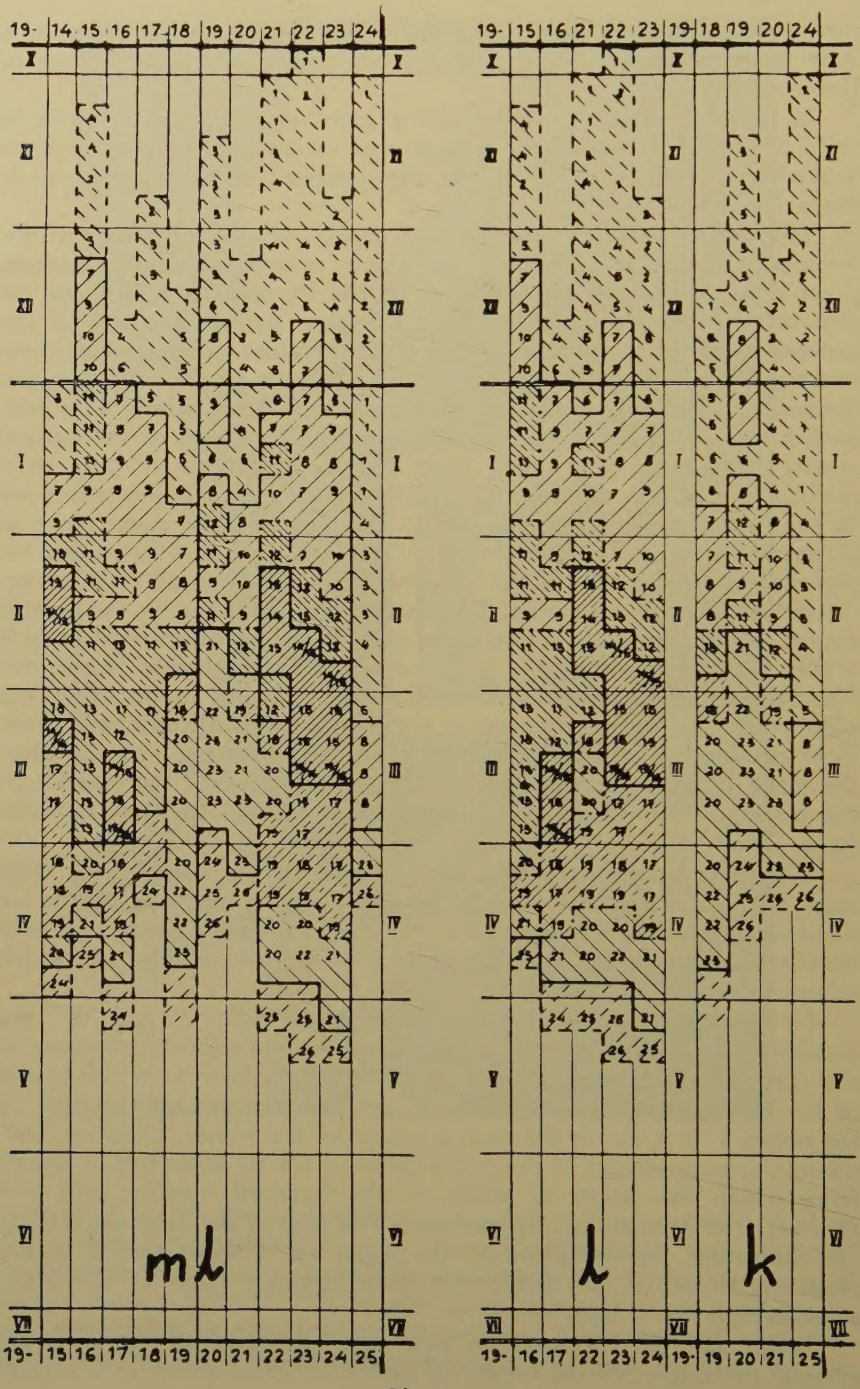


Figure 2.

situation on the one hand and the limits of the loose ice, the lanes, and ice banks on the other were transferred to special composite charts. The combination of the limits of the border of fast ice in the Gulf of Finland as obtained in this manner for group 8 is shown in chart eS8 in Figure 3, while chart eF8, in the middle of this figure, represents the combination of the limits for the loose ice for the same group. Finally the third chart of the figure, also eF8, gives the combination of the lanes and ice banks.

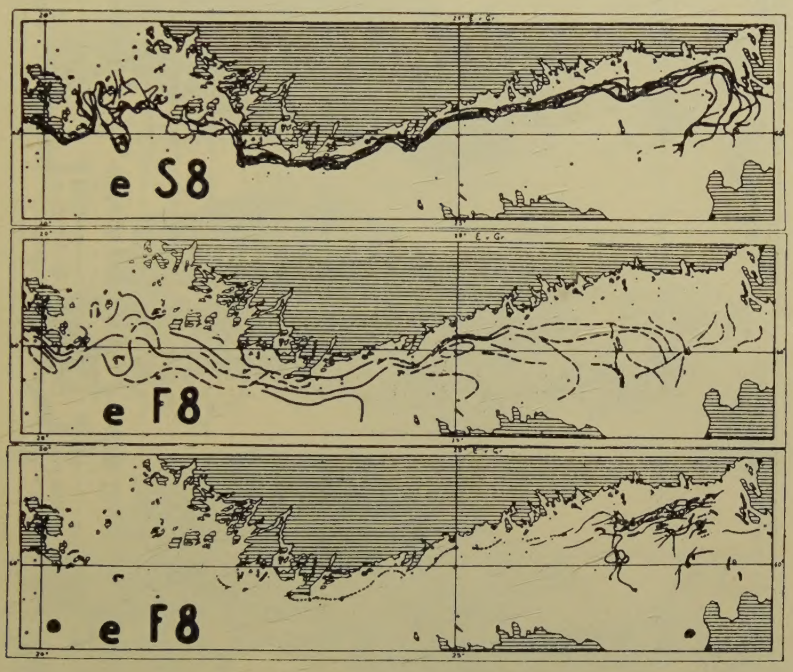


Figure 3.

From such composite charts for different groups, "S", for the fast ice, and "F", for loose ice, the ideal situations or normal of S-stages corresponding to the different points of the general course of the ice winter in five different sea regions were determined. The charts in Figure 4 show these normal or S-stages, 5, 6, 7, and 8, for the general course of the ice winter in the Gulf of Finland. In every stage the border of fast ice reaches from the coast to the thick double curve and it is within the limits of this curve that the edge of the border of fast ice remains during the ice situations corresponding to the stages in question. The thin curves outside the border of fast ice show the probability in tenths for the limits of the loose ice for the same situations ($2 = {}^{2}/_{10}$ etc.). The circles refer to the thin ice, the triangles to loose drift ice, and the squares to solid immobile ice. The

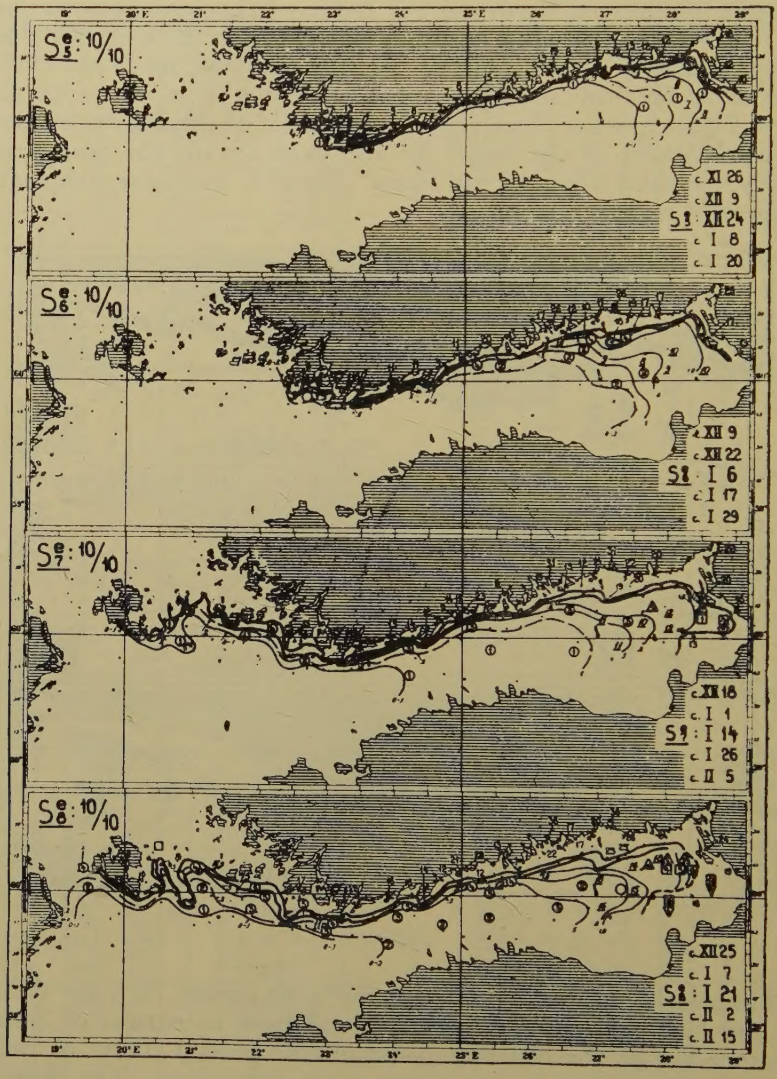


Figure 4.

numbers in the circles, triangles, and squares indicate the probability in tenths for the occurrence of the corresponding kinds af ice.

When all the stages for the general course of the ice winter in a sea area — so far, still detached from time — had been determined, the general course of the standard or normal winter for the sea area in question was obtained simply by arranging the stages according to growing, culminating, and decreasing states of the ice.

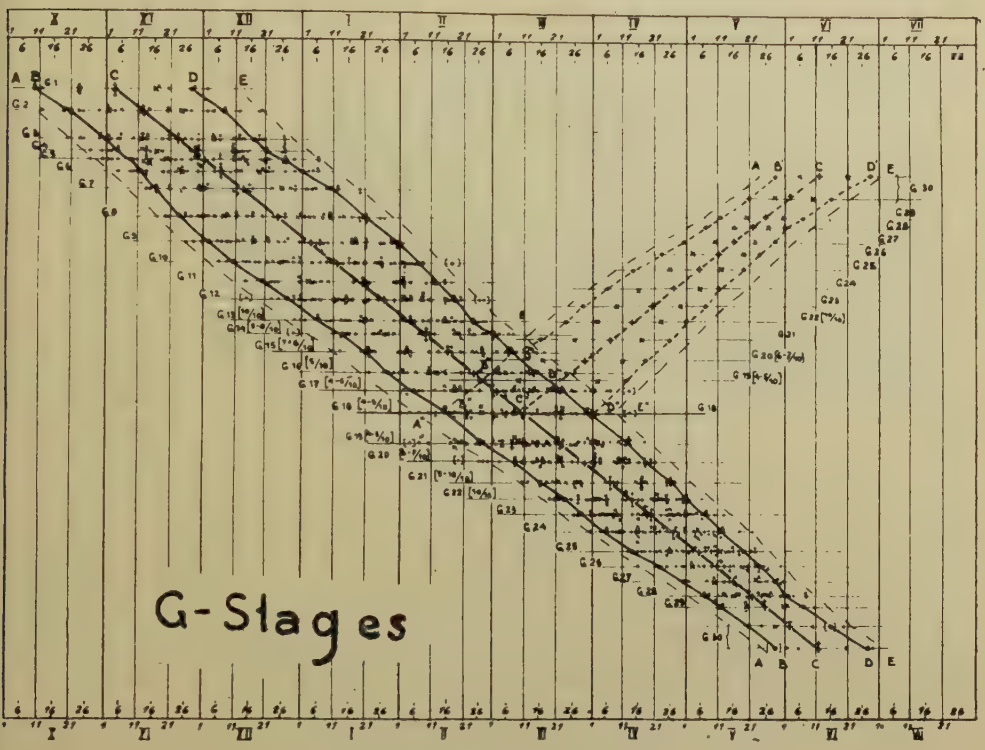


Figure 5.

As the comparison winter is to be a measure for the winter in regard to time also, the "time" must be restored to the course of the winter. In principle this was made by determining the average dates for the appearance of all the ice situations used for the construction of the different stages. These average dates form in the general course of the ice winter the mean dates not only for the appearance of the stages themselves but also for the corresponding ice situations. As the time-spread of the different ice situations which form the same normal stage of the ice winter is very great and in relation to the extent of cover may be compared with the considerable variation in the positions of the ice limits for a certain date, the time mobility of the normal stages must be correspondingly large. For this purpose it was necessary to determine, in addition to the average date for the appearance of a normal stage, the dates for its very early, early, retarded, and very retarded appearances. This was generally performed graphically by means of so-called time-diagrams. Such a diagram for the entire Finnish sea area is shown in Figure 5.

In this figure the lines drawn through the upright crosses indicate the average course of the normal winter. The small crosses and dots

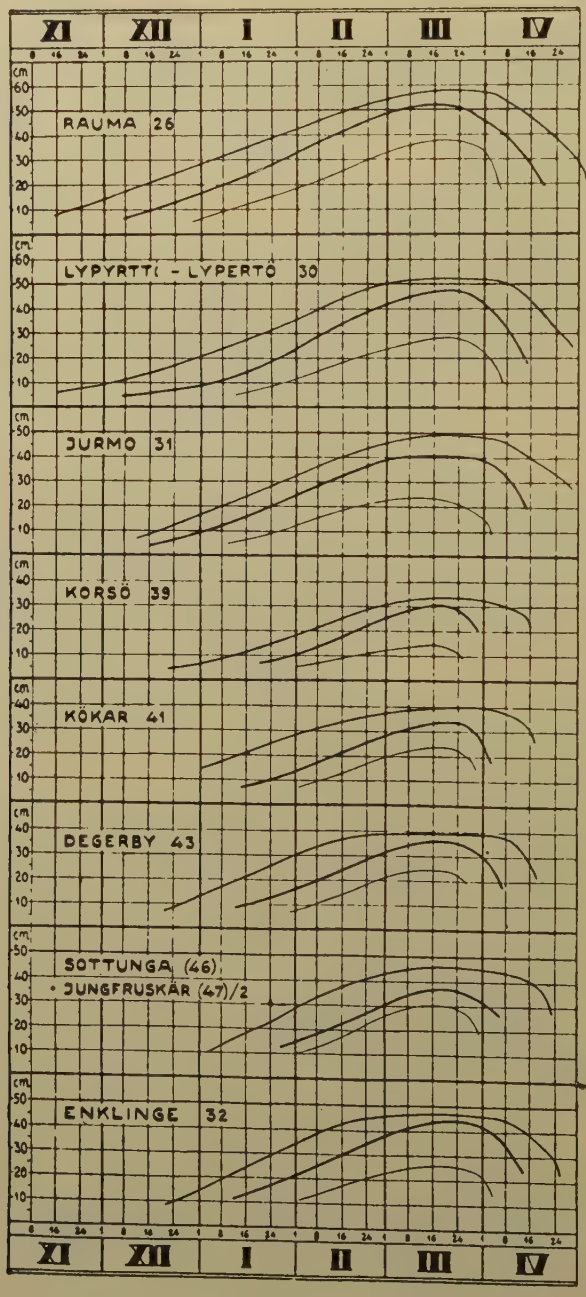

XI
XII
I
II
III
IV
cm
RAUMA 26
LYPYRTTI - LYPERTÖ 30
JURMO 31
KORSÖ 39
KÖKAR 41
DEGERBY 43
SOTTUNGA (46)
• JUNGFRUSKÄR (47)/2
ENKLINGE 32

Figure 6.

Figure 7.

on the lines drawn through the upright crosses parallel to the time axis represent the ice situations from which the corresponding general stage was determined; they also show the dates for these situations.

The ice thickness corresponding to a normal stage was determined by arranging the numbers for the ice thickness at different observation stations according to the schemes shown in Figure 2, in groups similar to those used for the ice situations. By means of these groups the ice thicknesses corresponding to the stages of a medium, a long, and a short normal winter were calculated. Figure 6 shows for the Archipelago the annual course of the ice thickness which was determined in this way for long, medium, and short normal winters.

In order to present information on the nature of the ice in the normal stages, the principal kinds of ice were indicated on the charts of the stages by the various signs mentioned above. The triangles thus signify loose drift ice, or ice which may break up and form lanes, perhaps moving a little, even in the height of winter. The squares denote immobile ice, frozen solid. The small circles show thin, newly formed ice.

Charts were prepared in this way for the normal stages in the Bothnian Bay (area *a*), the Quark (area *b*), the Bothnian Sea (area *c*), the Archipelago, the Aaland Sea, and the northern Baltic (area *d*),

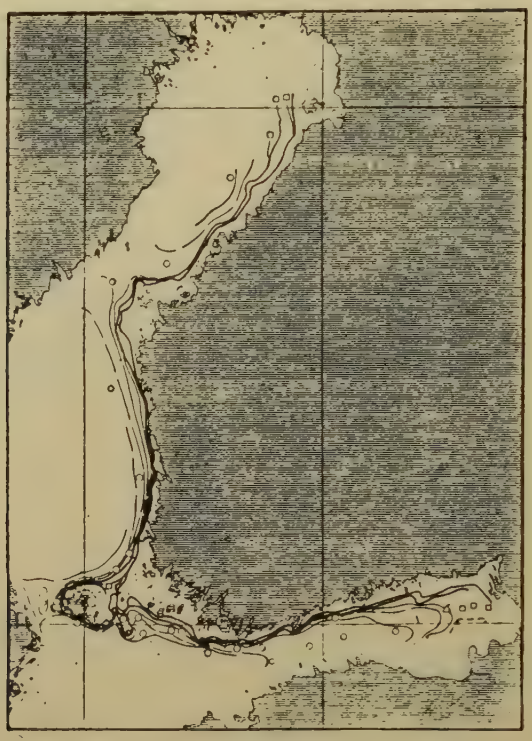


Figure 8.

and the Gulf of Finland (area *e*), as well as for the corresponding general stages for the entire Finnish sea-area which will be described later on, and which were determined from the S-stages. In these charts the principal elements of the ice situations are indicated as follows (Figure 7):—

The coastal border of fast ice occupies the area between the coast and the two heavy curves. The fine curves represent the probability of occurrence of loose drift ice outside the fast ice. The ice thickness is given by the numerals; those in italics refer to the ice outside the border of fast ice. The date is indicated by the series of dates of the stages, in which the date in large numerals in the middle of the series is the average date for the appearance of the normal stage and the corresponding ice situations; the dates above this relate to early and very early occurrences, and those below to retarded and very retarded occurrences.

When the normal stages for the different sea-areas (S-stages) had been determined, the fundamental stages for the entire sea-area or the so-called general or G-*stages* were deduced by directly combining all the normal stages having the same average date. In those cases in

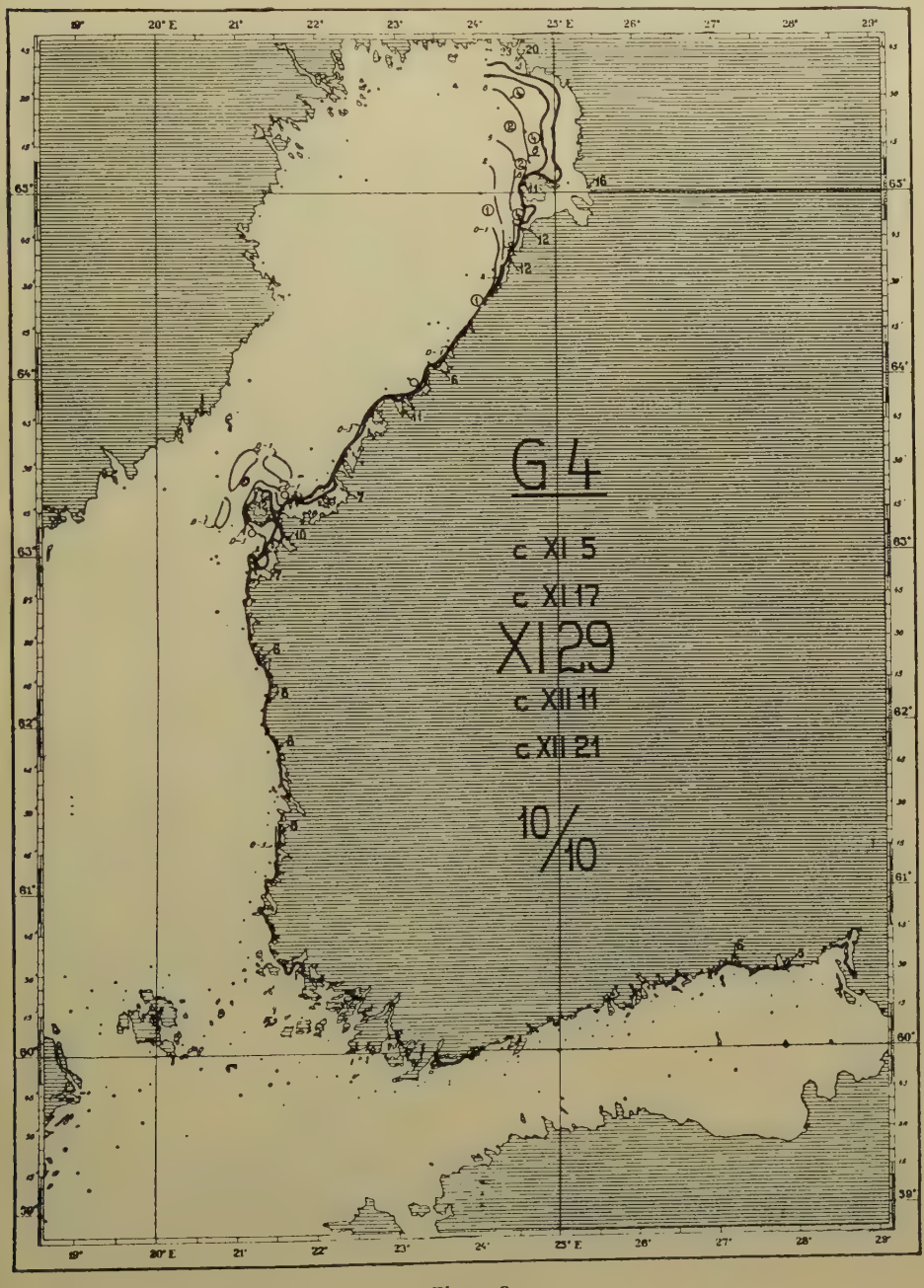


Figure 9.

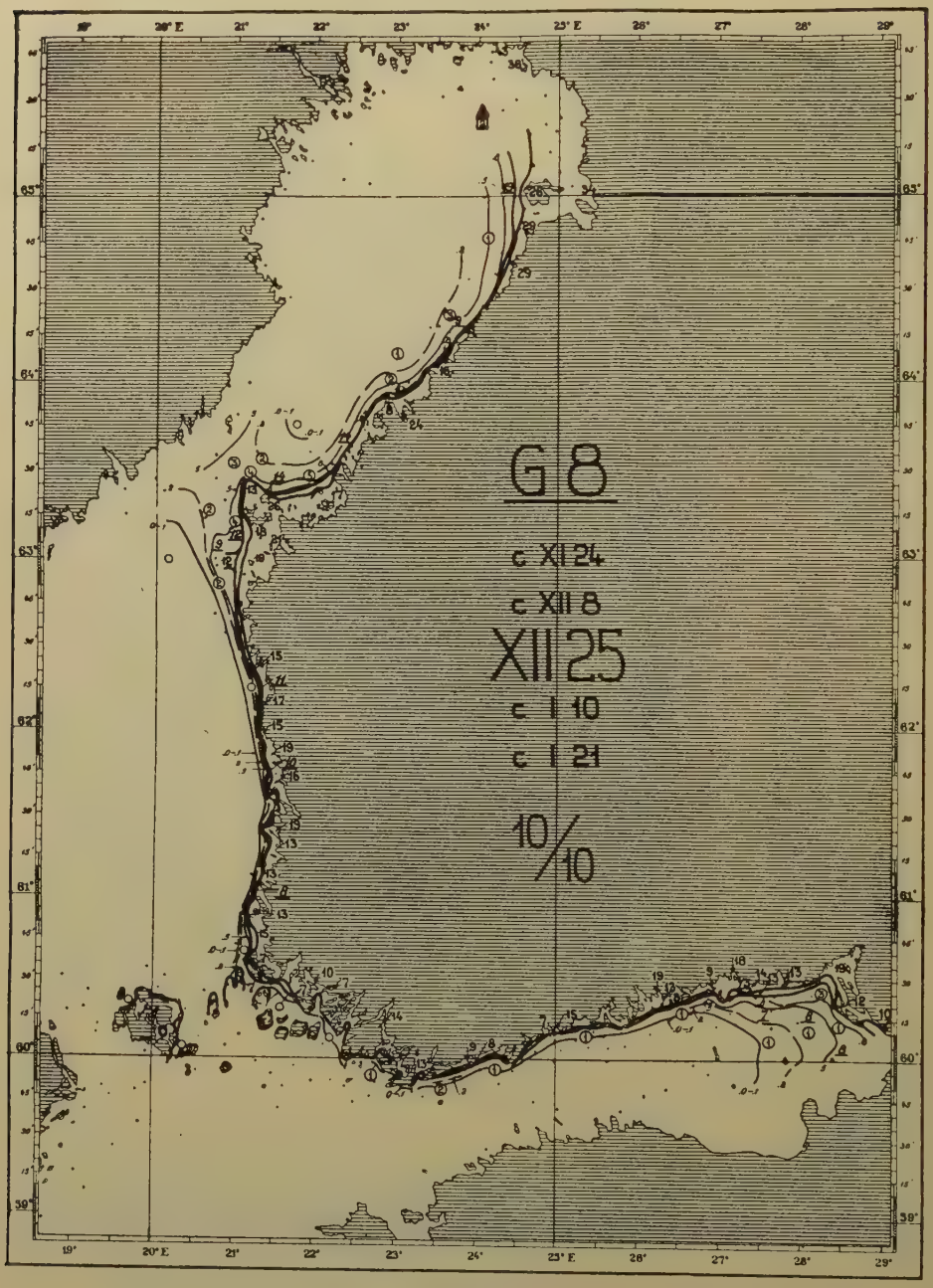


Figure 10.

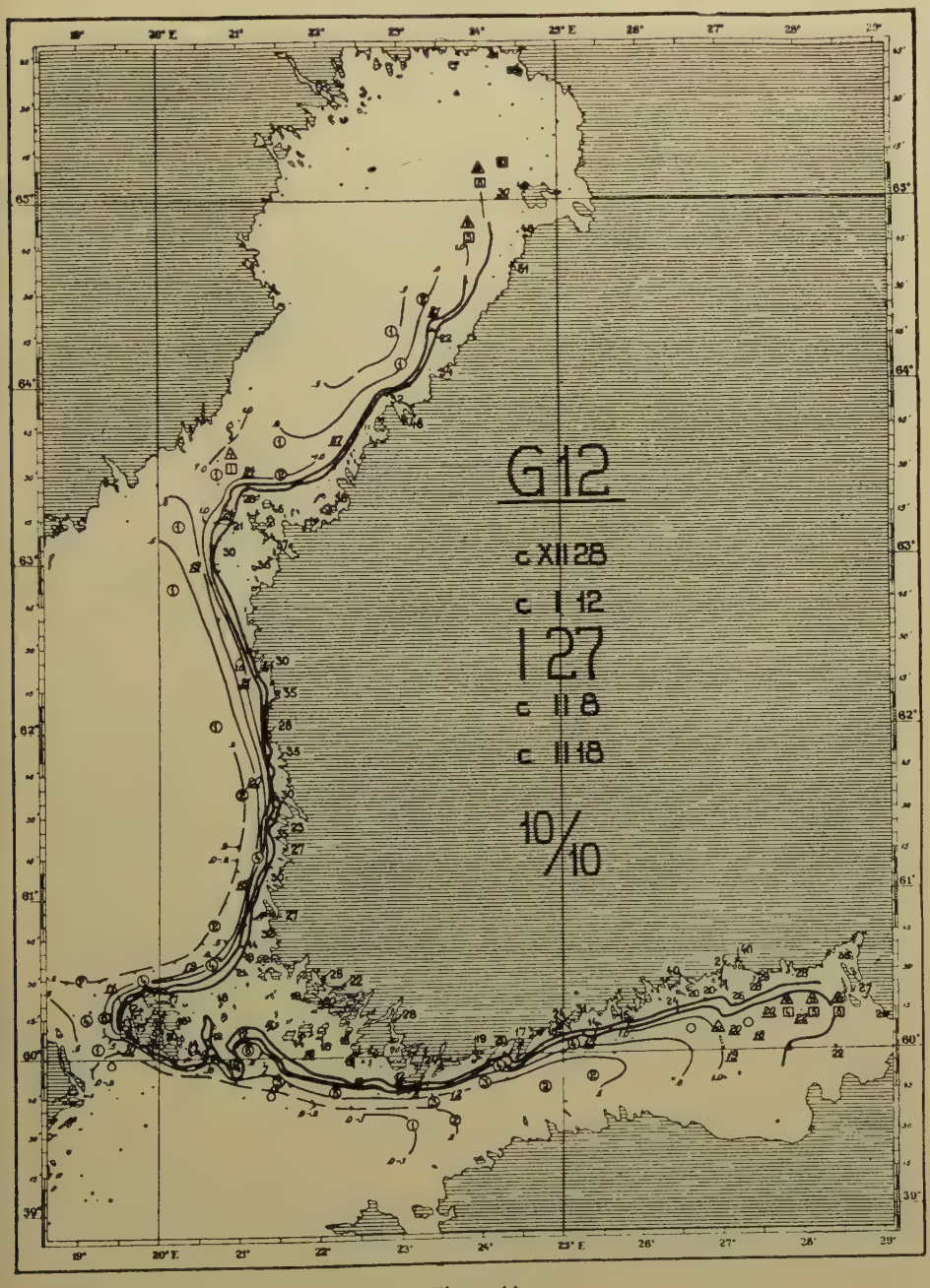


Figure 11.

which the probability for the annual occurrence was the same for the stages of the different sea-areas, the combination was easy, in contrast to the cases in which the probabilities differed. In the latter cases, combination was effected by means of frequency curves and frequency numbers.

As an example of the deduction of the general stages from the normal stages, we may take the general stage with the average date 20. January. This stage is constructed from the normal stages *a*9, *b*10, *c*8, *d*7, and *e*8 for the five sea-areas. The general stage without the dates, the indices for ice thickness, and the probability or frequency curves for the loose ice are shown in Figure 8. This general stage (the eleventh) represents that point in the general course of the ice winter at which the freezing on the Finnish coast has progressed so far that a bridge of fast ice joins Aaland with the Finnish mainland.

Finally, Figures 9, 10, and 11 give examples of the general stages. The first of these, Figure 9, shows the general stage G 4 with 29. November as the average date of appearance. In very early winters this stage is reached by 5. November; in very late winters there is only this slight amount of ice present at Christmas. Figure 10 shows the general stage G8 corresponding to the average freezing at Christmas. In very early winters the freezing reaches this stage about 24. November; in very retarded winters it is not reached until about 21. January. Figure 11 shows the general stage G12 with an average date of 27. January. In very early winters the amount of ice which this stage represents is found af Christmas; in very retarded winters it does not occur until about 18. February.

The numbers of S-sages constructed for the different regions were as follows:— the Bothnian Bay, 26; the Quark, 24; the Bothnian Sea, 26; the Archipelago, the Aaland Sea, and the North Baltic together, 25; and the Gulf of Finland, 28. The number of G-stages was 30.

A detailed description of the method is given in the author's paper "Über die Eisverhältnisse des baltischen Meeres an den Küsten Finnlands" (*Fennia* 64, Helsinki, 1937). The charts for all the S- and G-stages and the maps for "time with ice" are to be found in "Atlas der Eisverhältnisse des baltischen Meeres an den Küsten Finnlands" (*Fennia* 64, Helsinki: Anhang).

An Auxiliary Apparatus for Plankton Studies by means of the Sedimentation Method.

By

Per Haller Nielsen.

WHEN phytoplankton is counted in Utermöhl's reversed microscope, objects are often encountered which ought to be studied more carefully. It may be necessary to have them turned over or even moved to another microscope for examination under higher power in order to identify them. To facilitate work of this kind, the apparatus shown in Figure 1 has been constructed, by which slight movements of the water may be produced close to the object being studied.

The apparatus consists of a glass tube of 6 mm. outer diameter and 1 mm. thick, drawn out into a capillary with an opening of 0·4 — 0·5 mm. and bent as shown in Figure 1, at A. This capillary serves as a micropipette and micromanipulator. The pipette is attached to a mechanical stage by means of an arm, B. The mechanical stage is shown separately in Figure 2. It is mounted on the condensor stand by means of a swallow tail.

The micropipette is connected with an injection syringe, C, through a rubber tube, D. The syringe is placed in an elastic holder, E, screwed on to the microscope.

When an object is encountered which needs further examination, its position is noted and the rest of the field is counted. The cover-glass on top of the cylinder is then removed, and some of the water is pipetted off. The apparatus is put into place and moved so far down by the screw on the condensor stand that the point of the pipette is dipped into the water. A little water is sucked into the pipette by

means of the syringe, so that it reaches 1—1½ cm. into the thicker part of the pipette.

The apparatus is coarsely adjusted macroscopically by pushing and twisting the arm. As soon as the point of the pipette appears to lie over the axis of the objective, the finer adjustment is carried out by means of the screws of the special mechanical stage of the apparatus. The pipette is in place when its point is close above the bottom and is clearly seen in the microscope.

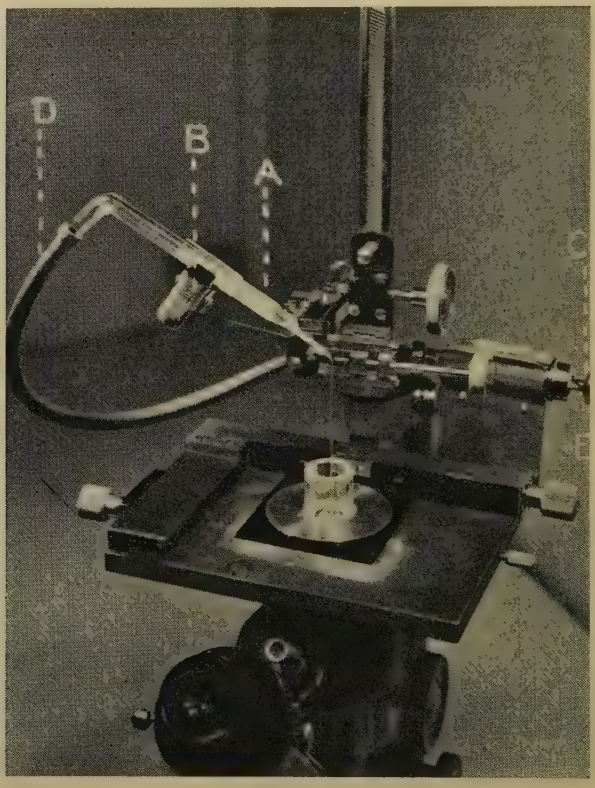


Figure 1.

The object to be studied is placed close to the mouth of the pipette and movements of the water are effected by pushing or sucking of the syringe.

If the object is to be moved to another microscope, it is placed under the point of the pipette, which has first been completely emptied of water, and the object is then sucked into the pipette by using the syringe. The transfer into the pipette may be controlled under the

microscope. The contents of the pipette are afterwards placed on a slide, and are ready for further examination.

Figure 2.

This apparatus has been produced by Mr. Petter Pettersen, instrument maker at the Institute of Physics, University of Oslo.

Precipitate in Sea-Water Samples for the Study of Plankton.

By

Ottar Nordli.

DURING post-war studies of quantitative phytoplankton samples by means of the sedimentation method, a flaky precipitate, occurring in some bottles, hindered effective sedimentation and the samples had to be discarded.

The samples had been preserved with neutralized formalin, carefully filtered.

Precipitate from many bottles was concentrated and subjected to chemical study by Dr. O. W. Rambech. He concluded that the precipitate was silicate, probably calcium silicate.

When the precipitate occurred in so many samples as to reduce considerably the value of the whole phytoplankton material, the reason might perhaps have been that the quality of the glass used for making these post-war bottles was different from that used previously.

Neutralized formalin has been in use for many years as a preservative for quantitative phytoplankton samples. According to Zo Bell and Brown (1944)[1]) only strong acids compete with formalin as effective preservatives for sea water. Since, however, for quantitative phytoplankton work acid preservatives are not suitable, the coccolithophorides being destroyed, formalin may still be considered the best preservative for this purpose.

If 2·5 ml. or more of 10 % formaldehyde is added to 100 ml. sea-water sample, preservation is usually good. According to the experience mentioned above, care should be taken, however, to avoid glassware which is not resistant to fluids with pH of 8—8·5. Storage at low temperature will retard the occurrence of silicates in the bottles.

[1]) C. E. Zo Bell and Barbara F. Brown. — Journ. Mar. Res. 5, 1944.

The Use of Bones, other than Otoliths, in Determining the Age and Growth-Rate of Fishes.

By

M. D. Menon.

With an Appendix by T. J. Hart.

Introduction.

Determination of the age of fishes by means of scales, otoliths, and certain bony parts has been in use for a very long time in fishery research, and the literature in the subject is very large and diffuse. S. Thomson (1904), Monastuirsky (1926), and Van Oosten (1929) give very elaborate reviews of the scale method. Chugunov (1926) gives a detailed analysis of the literature (mainly by Russian workers) of age determination by bones, and Graham (1929) has given a most valuable survey of some seventy papers on age determination of fishes by the use of scales, otoliths, and bones. Important works by Arnold (1911), Freidenfelt (1922), Kaganowskaia (1933), and other more recent workers have not been included in any of the above reviews. We have not been able to see two Russian papers listed in the bibliography, but have included short abstracts of them taken from the work of Chugunov (1926). The aim of this paper is therefore to provide a more up-to-date and more comprehensive survey than any yet available of the literature on age determination of fishes by the use of bones, giving the methods employed and the calculations used by the many different workers.

Survey of the literature.

Heincke and his associates (1904) working on the food fishes of the North Sea were the first to observe and utilize the annual zones or rings appearing in several parts of the bony skeleton for age determination in those fishes (especially gadoids and some flatfishes)

in which the otoliths were too thick or irregular for the purpose. Heincke found that growth in length, breadth, and thickness of all the bones of the skeleton is periodic and that the annual growth is marked in definite layers of varying clarity. At best, the bones when air-dried show two clear zones to each year — one white, one dark and translucent when viewed in reflected light. The slowing down of growth in winter is marked by the beginning of the white layer, but the boundaries between the layers are of varying sharpness. Heincke further established that the regions displaying these age-zones most clearly are the concavities of the vertebral centra, the opercular bones, especially the sub- and inter-opercula, certain parts of the girdles, especially the coracoid and scapula, the urostyle, the epural, hypural, and the hyomandibular. He also noted that the bones best suited for age determination varied in different fishes. In plaice, turbot, and soles he found it best to study the vertebrae; in gadoids the flat bones of the pectoral girdle, especially (in the cod) the coracoid and scapula; in haddock the rounded swollen part of the clavicle showed unmistakable evidence of age in section, and in this fish the vertebrae were also good; in herring the vertebrae gave best results but in the 0, I, and II age-groups he found that the opercular bones also gave satisfactory readings.

According to Heincke these rings or bands when visible in the bones are as good age indicators as those of the otoliths, on the argument that their number agrees with the number of otolith rings in one and the same fish. Cunningham (1905) discussed the utility and validity of the markings in bones and otoliths for age determination in plaice and cod. In the plaice he examined the coracoid, operculum, and vertebrae. He disagreed with Heincke, finding no sufficiently clear rings on the opercular bones, but observed that there were "more or less parallel lines and zones in the coracoid element of the pectoral girdle, which consists of calcified cartilage". He also observed that there were rings on the vertebral faces, but held that neither these nor the coracoid gave such good results as otoliths. In the coracoid he fixed the junction of the bony rod with the cartilaginous plate as its centre of growth, and wherever there was complete calcification he found lines parallel to one another; the scapula also showed similar lines but all were too indistinct to be satisfactory. He also observed that the concave faces of the vertebral centra showed light opaque white bands alternating with dark transparent lines when viewed in reflected light. These he presumed to be annual but found it impossible to read the indistinct central ones with certainty.

In the cod, Cunningham examined the bones of the pectoral girdle, the operculum, the skull, and the vertebral column and found that the cleithrum, coracoid, scapula, skull bones, and opercula showed certain parallel lines which were much too indistinct to be useful for age determination. He found too, that the vertebral column shows parallel zones and rings in almost all of its component parts but that

the difficulty in deciphering them led to conflicting results. In general, Cunningham completely disagreed with Heincke on the utility of bones for age determination in plaice and cod.

Heincke (1908) further elaborated his earlier observations. He was emphatic as to the annual nature of the zones, the opaque broad white zone being laid down in spring and early summer; the thin, transparent, dark zone in late summer and autumn, with a sharp line marking the cessation of growth in winter. He observed that besides the appearance of the same number of rings in the bones as in the otoliths in the same fish, there was most clear corroborative manifestation in the bones of the same stronger or weaker growths of the year that one might find in the otolith. He also claimed that in the different skeletal parts, especially the broad, thin flat bones like the operculum, "jaw apparatus"(!), girdles, and skull, all the narrow rings laid down in advanced age could clearly be distinguished but that this is not possible with either the otoliths or the scales. In the plaice, in particular, he found the early year-rings were clear in the otoliths, the later ones in the bones.

In order to make the annual rings more readily visible, Heincke recommended special methods of treating the bones. After boiling and cleaning them, he advised first dehydration with absolute alcohol and then removal of fat by soaking in benzine or ether, with final air drying. He claimed that bones so treated, when placed in alcohol on a black background, show up the year-rings quite clearly ("as clear as a photographic image"!). Sometimes he found that the rings became clearer in glycerine, after a short immersion in alcohol. He warns against the danger of keeping the bones in absolute alcohol too long at any stage, because the complete penetration by this reagent blurs the picture. At the end of his paper Heincke gave some very fine photographs of pencil drawings of vertebra, sub-operculum, metapterygoid, and otoliths of plaice, turbot, and cod. From his studies of these species he arrived at general conclusions regarding the different rates of growth in males and females and the gradual decline in growth-rate with advancing age which have been almost completely substantiated by later workers using other methods of age determination.

Haempel (1910) used opercula, vertebrae, and the upper jaw for age determination in the Danube salmon, *Salmo hucho*. After boiling the head he cleaned these bones and stored them in 96 % alcohol. He claimed that the number of light and dark zones at the proximal ends of these bones corresponded exactly with the number of rings on scales and otoliths, the rings on the vertebrae giving the best practical results. The occurrence of some false rings, in the form of "double ringing", was noted but he claimed that these could easily be distinguished by their discontinuous nature. He attributed this doubling and indistinct zoning to influences of temperature variation and food supply. His results permitted the construction of a very

informative graph correlating weight, length, and age of the Danube salmon. Comparing his results with earlier work by Salomon[1]), he claimed that the latter's methods yielded values which were much too low. This paper by Haempel includes a short general discussion of the methods of age assessment in fishes from length-frequency curves, scales, otoliths, and bones.

Redeke and Tesch (1912) found that age determination by otoliths and scales was not feasible in the sole *(Solea vulgaris)* but that both faces of the vertebral centra showed quite distinct annual rings. The posterior faces, being more concave, show the rings a trifle more widely separated, and therefore more clearly, than the anterior ones.

Tereschenko (1913) working on voblya *(Rutilus rutilus)* used the cleithrum for age determination. He prepared his material by boiling and cleaning, with little maceration. The cleithra were then air-dried and placed in labelled packets. The measurements were carried out under a low-power lens with transmitted light against a black background, the bones being immersed in spirit which was found to improve the definition of the annual layers. He claimed that the so-called supplementary rings were but temporary growth checks and could be recognized by their weak and incomplete formation, in contrast with the bold and complete formation of the true annual rings. Tereschenko also noted that the winter zone, though formed in winter, only became apparent in April and May, and that it was observable much earlier in young fish than in mature ones. The cleithrum was measured by projecting its image onto a board, on which the essential points such as the centre of growth, length of cleithrum in its first year (to the first ring), second year, etc., and the farthest point attained were marked. The measurements on the board were determined from a millimetre scale subjected to the same magnification as the cleithrum. These measurements in the voblya cleithrum were carried out along a straight line from the centre, which Tereschenko fixed as "the point of intersection of the surface of the base with the process of the bone that goes forward". He back-calculated the lengths and rate of growth by using the Lea-Dahl formula $\frac{L}{C} \quad \frac{lx}{cx}$, i. e., $lx \quad \frac{L}{C} cx$. The ratio, length of fish to length of cleithrum, decreased with age and varied with individual fluctuations in size. The results given by the Lea-Dahl formula differed markedly from the observed values. Tereschenko therefore introduced a compensating co-efficient calculated from the mean ratio for the required age, and the mean ratio of the investigated fish of a definite age-class. The formula then became $Lx = \frac{L}{l} \times lx \times K$, where L = length of fish, l = length of cleithrum, Lx = the required length of fish at X years of age, lx = the length of the cleithrum at X years of age and K = the

[1]) This paper was not available to me.

variable co-efficient. The formula gave very interesting results agreeing well with actually observed lengths.

Thielemann (1916) used otoliths and vertebrae for age determination in *Solea vulgaris*. He admits that the vertebral rings are the best basis for age determination in this species and the easiest to use. Even with the oldest year-group he found that the vertebrae showed very clear rings. In spite of this, he gave preference to the otolith method and used vertebrae only to confirm his otolith readings; in any doubtful agreements he always took the readings of the otolith sections as the correct ones. The reasons for this apparently illogical preference are not clear, more especially since he found that most instances of peculiar growth were reflected in the same way in vertebrae and in otoliths. The intermediary false rings found in some otoliths and vertebrae were interpreted as probable variations in the feeding conditions. He prepared the vertebrae by the method suggested by Heincke — boiling, cleaning, and removal of fat by alcohol and benzine. For examination of the rings he found it best to place them in xylol. Thielemann gives some very fine reproductions of pencil drawings of vertebrae.

Tereschenko (1917) publishes a study of the Volga bream, *Abramis brama*, in which the cleithrum was used for age determination and back-calculation was applied, but some essential deviations were made from the procedure adopted with *Rutilus rutilus*. The cleithrum of the bream is a bent one, and measurements made along a straight line as worked out for the roach do not give true results. With the bream therefore Tereschenko made measurements along a different section for each annual growth as shown in Figure 1 and calculated the total "size" of the cleithrum by summing the measurements for the several years. Also, he made no use of the variable co-efficient K introduced for the study of voblya because in *Abramis brama* he did not find any fluctuation in the ratio of length of cleithrum to length of fish, and so took it as constant. Further, he did not observe any essential divergence in the calculated sizes of fish from actually observed lengths.

Nilsson (1914) found good agreement between the numbers of annual rings on vertebrae, scales, and otoliths of mackerel. He observed that the vertebrae gave a high proportion of ambiguous results, however, and accordingly used scales and otoliths in his work on this species.

In a later work Nilsson (1916) used the operculum for age determination in perch. He prepared the material simply by boiling, cleaning, and air-drying the bone and his measurements were all carried out in a straight line with dividers alone. Frequently he examined opercula and scales from the same fish, and found considerable agreement between the two. The central point for his measurements was the centre of the articulatory process as shown in Figure 2. The back-calculations worked by the Lea-Dahl formula

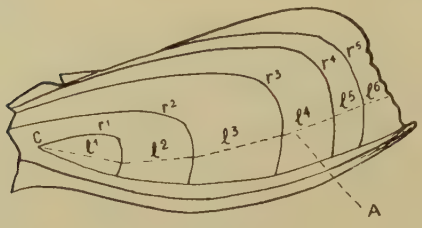


Figure 1.

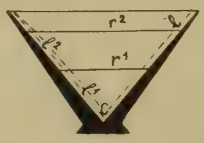


Figure 3.

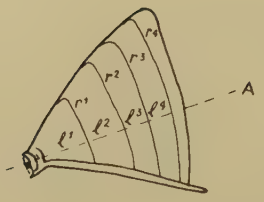


Figure 2a.

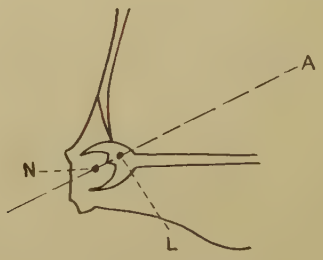


Figure 2b.

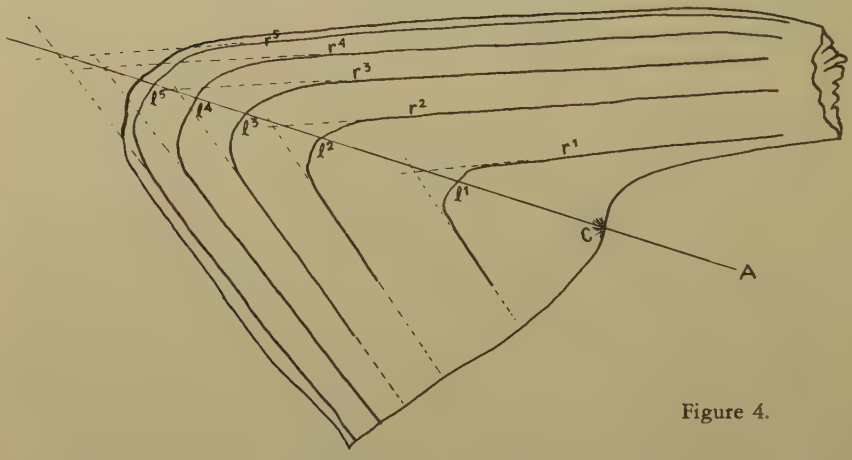


Figure 4.

Figure 1. Cleithrum of *Abramis brama*. (After Tereschenko, 1917).
Figure 2a. Operculum of Perch. (After Wundsch, 1927).
Figure 2b. Articulatory head region of operculum of Perch. (After Le Cren, 1947).
Figure 3. One concave face of the vertebral centrum in longitudinal section. (After Aikawa, 1937).
Figure 4. Diagrammatic representation of the supra occipital crest of *Gadus minutus* to show the annual rings and the axis of measurement. (Menon, 1949).
C = Centre of Growth. r^1, r^2, r^3, etc. = Annual rings.
l^1, l^2, l^3, etc. = Length of the respective annual rings from the centre of growth.
A = Axis of measurement. N = The centre used by Nilsson.
L = The centre used by Le Cren.

gave a deviation of ± 5 mm. which he regarded as understandable and negligible.

Derjavin (1922) used the cleithrum in his study of *Acipenser stellatus*. The cleithrum is very bent so he cut off all processes that interfered with the horizontal position of the bone under the lens, and the measurements were made along the rib of the cleithrum, along separate and different sections for each year-growth. Since these bones in the large fish that he dealt with were of large dimensions, the measurements are said to have been carried out straight on the bone using a pair of dividers only.

The otoliths and vertebrae were used by Connolly (1922) for the age determination of *Lophius piscatorius* from the Bay of Fundy.

The age of *Lucioperca* of Lake Vanan and Hjalman lake was studied by Freidenfelt (1922) using scales and vertebrae. The vertebrae used were all taken from the most posterior part of the thorax. They were cut along their length and the surfaces were drawn under a dissecting microscope using an Abbe camera lucida. These surfaces showed broad white zones alternating with narrow transparent zones in transmitted light. These narrow zones were found to correspond with the "closely striated" zones of the scales. Evaluation of growth was made by the Lea-Dahl formula. Freidenfelt examined the question of growth and the validity of the method critically under the following four headings:—

1. Whether there was a positive correlation between growth of the fish and growth of the scales and vertebrae.
2. Whether the formation of the zones was annual, occurring regularly at particular seasons.
3. Whether the increment in growth occurred at their borders, and whether the year-rings, once formed, changed either in shape or size.
4. Whether there was any correlation between the lengths calculated from the scales and vertebrae and empirical lengths.

He found there was positive correlation between growth of the fish and growth of scales and vertebrae, and that the zones were annual, being laid down at particular seasons. He observed that in *Lucioperca* the first rings may not be laid down in the first year of life. There was a fair amount of correlation between the calculated lengths and the observed lengths. The corresponding zones in the scales and vertebrae were not always formed simultaneously. In young fish they were formed in vertebrae much later than on the scales; but with the older age-groups the period of formation of these zones in the two more or less synchronized. He also found that there was a possibility of a slight later addition to the first year-growth in scales and a possible shrinkage in the width of the second year-ring. But in the vertebrae the first year-ring remained unchanged after its formation.

Holtzmayer (1924) studied the age of *Acipenser* by cutting

sections of the marginal pectoral ray. He found that this ray, sectioned at the proximal end, shows definite and alternating broad dark rings and narrow light rings with a third sharp line of demarcation between them. The dark broad bands were formed during the period of intense growth in summer; the thin narrow zones at the period of slowest growth in summer, and the lines of separation were laid down at the period of slowest growth in winter. The importance of this work lies in the fact that all the material Holtzmayer worked on was from Prof. Ostroumoff's famous sturgeon culture, and hence of known age. Thus the close agreement between the age as calculated from these pectoral ray rings and the known age is alone sufficient to confirm the validity of the method at least in *Acipenser*.

Chugunov (1925) elaborated the above method of age determination in sturgeons in his treatise on the sturgeons of the Black Sea. He examined the caudal fulcra also, but found that the fin rays were more convenient. The first bony fin ray was the one used and was cleaned off thoroughly. This was best accomplished by making a deep cut in the pectoral girdle up to the articulatory head of the first ray and then cutting through the uniting ligaments with a twisting motion of the knife; the ray could then be bent back and peeled out of its articulatory socket. The rays were then boiled, cleaned, dried, and stored in labelled packets. For examination of the rings he cut sections of the dried ray with a fretsaw fitted with two thin parallel blades separated by a thin copper plate arranged to cut sections of 0·5 mm. in thickness. The sections were made within 1·0 to 1·5 cm. of the proximal end of the ray (the articulatory head). They were then mounted in Canada balsam. Age determination was carried out under the low power of a microscope with transmitted light. False rings could be distinguished by their weak formation shown up by manipulating the lighting. Chugunov claims that with direct lighting and a dark reflector they totally disappeared. In very old specimens it was found that cavities are formed in the centre of the ray, tending to obliterate the first ring, but some traces of it could almost always be discerned under high power. In the few cases where even this was not possible Chugunov advocated arbitrary assignment of the position of the first ring from calculations based on the rest of the material ("normal growth-rate"). He claims that by these means it was possible accurately to determine the age and growth-rate of sturgeons.

Chugunov further (1926) has given a most valuable general account of the use of bones in determining the age of fishes, based mainly on Russian work. Graham (1929) has already given a brief summary of this paper, but in view of its great importance in relation to my own work described below a more detailed résumé is necessary. After a detailed review of the work of Tereschenko, Derjavin, Nilsson, and Soldatov already referred to, he deals at length with the practical details of the methods of collecting material, mode

of age determination using different bones, and application of the measurements to practical calculations. The most important findings under these main headings are:—

1. Method of collection.

(a) The best results are to be got from the bones of fresh fish; frozen fish sometimes give fairly good results but salted or otherwise preserved fish are useless. For collecting the bones of the pectoral girdle and opercular apparatus it is best to cut off the head together with the pectoral fins, but in large specimens it may be necessary to remove individual bones by deep cuts.

(b) The serial number of each fish dealt with should be written on a separate label which is folded and placed in the mouth of each head. These labels should never be placed under the hyoid bones whence they are likely to fall out during boiling.

(c) It is better to underboil than to overboil the bones; overboiling tends to make them blurred and opaque.

(d) When forced to deal with separate bones from the same fish it is best to parcel them all together in a piece of cloth before boiling. After boiling the bones are severally cleaned with a tooth-brush and laid out in separate labelled boxes for drying and storage.

(e) Large and massive bones require to be boiled for a long time, with further treatment after boiling to remove fat. The best method is to soak them for a few days in a mixture of 2 parts benzine and 1 part ether, changing the liquid periodically. In some cases it may be necessary to file and plane the surfaces of the bones.

(f) Fin rays should be collected as described in Chugunov's previous paper mentioned above.

2. Age determination.

(a) By the cleithrum. Placing the bone in spirit increases the sharpness of definition of the zones. The point on the bone from which all measurements are made must be constant. The direction of measurement (or the axis of measurements) also should be constant. For small and flat cleithra the centre usually taken is the point of intersection of the surface of the base with the projecting process of the bone, and the measurements are made in a straight line. For bent bones all processes and projections that mar the horizontal surface of the bone under a lens must be cut off and the measurements made along the rib of the cleithrum. Further, with these bent bones, the measurement for each zone or year is made along a different but constant[1]) section, and the size of the cleithrum for any year is obtained by summing the growths of previous years. Back-calculations are made by the Lea - Dahl formula; a slide rule is specifically recommended. Before measuring the cleithrum, it is best to mark the centre and the annual layers

[1]) i.e., the same in different fishes.

along the line of measurement. It will be realized that all these details are from the works of Tereschenko and Derjavin which have already been discussed above, but Chugunov was at pains to verify the validity of the method by reference to the material from Ostroumoff's sturgeon culture of known age.

(b) By the operculum. The external position of this flattened bone frequently made it easier to work with than the cleithrum. In small fishes, if the material is brought from cold to about 70° C., the annual rings and layers come out extremely clearly. In large fishes the operculum frequently shows lumps and ridges which must be cut and filed away to make the rings clear. Thin transparent opercula may require staining with violet or aniline ink or picrocarmine. Picrocarmine stains the older layers yellow and younger ones rosy. Chugunov compared the work of Nilsson with the data of Svetovedoy on perch, and found that Nilsson's calculations, taking the centre of the articulatory head of the operculum as the centre of measurement, gave very different values from those arrived at by the study of scales or by direct observation of cultures; but that if one takes the middle of the inner edge of the articulatory head as the centre of measurement of the operculum very harmonious results are arrived at. He gave some data on this. One interesting observation was that measurements taken from the centre of articulatory heads gave lower values than those taken from the centre of the inner angle of the flat part of the bone, and that this may be due to increased development of the supporting articulatory parts with age.

(c) By the pectoral fin ray. The annual nature of the layering in the fin rays in several fishes was first put forward by Kler[1]) and experimentally confirmed by Holtzmayer (1924) whose methods of collecting and cross-sectioning of the material have already been described. In measurements and calculations the greatest difficulty lies in fixing the central starting point. Chugunov has explained how this difficulty was overcome by examining the valuable sterlet material on known size and age from the Sea of Azov. It was found best to measure along the lower process of the cross-section which shows the rings most clearly. The centre was etablished on the longitudinal diameter of growth of the first year at a point about $^1/_3$ of the diameter away from the boundary of the first winter layers. From this point the measurements are carried out along a line straight down the lower side process following the line of greatest growth; they are made either with an eye-piece micrometer or a drawing apparatus and need great care, as an error of one to one-and-a-half micrometer divisions will result in an error of several centimetres in the calculated values. Sections with long side processes or rays with

[1]) Not seen by me.

inward growths are not suitable for study. Calculations of growth with the Lea-Dahl formula gave very good agreement with actual measurements, which received further confirmation from their close agreement with the measurements of the sverioga of the Sea of Azov.

In a general account of the methods of fishery research Wundsch (1927) refers to the work of Arnold, Freidenfelt and Nilsson. He held that scales are best for preliminary assessment of the age of any fish.

Sella (1930) based his observations on the age and growth-rate of tuna on the vertebrae. The vertebral centra of the tuna show alternating bands of transparent and opaque zones very clearly. From a study of the vertebral centra he has followed their growth over 14 years. It is rather curious that the annual growth increment remains the same in all the 14 years. It may be that this unvarying rate of growth is due to his disregard of sex in his treatment of the data.

Scofield (1931) used the operculum of bass *(Roccus lineatus)* for checking age determination by scales. The operculum was boiled, cleaned, and dried, and when examined in water the annual markings stood out as dark lines between cream-coloured zones. Though the first annual lines were inconspicuous, he was confident that he could detect them on close examination.

To determine the age and growth of *Silurus glanis* of the Aral Sea, Mikhin (1931) used the pectoral fin rays, using the method employed by Probatov[1]) (1929). Mikhin found that the observed lengths and ages compared extremely well with the calculated lengths and ages derived from the pectoral fin zonations.

The question of age determination in the spur dogfish, *Squalus acanthias (Acanthias vulgaris)*, has been studied by Madame Kaganowskaia (1933). She found that the vertebrae, scales, and teeth gave no reliable indications of age, but that the two dorsal spines showed unmistakable annual zones on their enamel sheaths. The surface of the spines of yearling spur-dogs was light grey in colour, but older specimens showed very clear bands of dark grey. With increase in length there was a corresponding increase in the number of bands on the spine, and it was claimed that the bands were analogous to the winter rings of the scales and bones of teleosts. The annual bands were very close together in some individuals thought to be over 18 years of age — so crowded that they could be counted in a few specimens only. The bands were clearer on the posterior spine than on the anterior one. Kaganowskaia gives a most suggestive table showing mean length at each year of age, of which the most remarkable feature is that the spur-dog would appear to have a uniform growth-rate throughout its life from the second to the twenty-fifth year! This may be due to treatment of the data without distinction of sex

[1]) Not seen by me.

or to selective action in the different nets used to catch the specimens. Though no means of checking the validity of the method are advanced, the paper is of great interest as an attempt at age determination of elasmobranchs which have even to this day received little or no attention from this point of view.

Paspalleff (1934) used otoliths and opercular bones to determine the age of *Bothus maeoticus*. The bones were boiled and cleaned mechanically and in some the fat was removed with xylol. He found that the interoperculum of the left side gave the best results. It is a thin bone and shows two kinds of zones, one transparent and soft, the other hard and less transparent. The harder material forms white lines and ribs on the bone. He found that often, when the otolith could not be read satisfactorily, the interoperculum presented no difficulty, and that especially in the oldest specimens its use was essential for age determination.

Klimowa (1935) used the operculum, sections of pectoral fin rays, and scales for the assessment of age in *Lucioperca lucioperca* from Lake Onega. She found that the pectoral fin ray in section showed very clear and unmistakable indications of age.

To determine the age of the Kama sterlet (*Acipenser ruthenus*) Probatov (1935 a) used transverse sections of the first osseous ray of the pectoral fin which gave very clear and distinct annual rings. In a subsequent study (1935, b) of the freshwater fishes of the Amur, he found it best to use cross-sections of the pectoral fin rays for age determination of most of the older fishes, in preference to the scales which presented a very complicated picture due to the presence of false rings on them. He used the pectoral fin ray to determine the age in *Cyprinus carpio*, *Carassius auratus gibelio*, *Ctenopharyngodon idella*, *Hypophthalmichthys molitrix*, *Erythroculter erythropterus*, *Parabramis pekinensis*, *Pseudaspius leptocephalus*, *Elopichthys bambusa*, *Hemibarbus labeo*, *Leuciscus waleckii*, *Coregonus ussuriensis*, *Parasilurus asotus*, *Brachymystax lenok*, and *Ophicephalus argus*.

Roper (1936) also used both scales and opercula for age study of the perch (*Perca fluviatilis*). He found that in the opercula the zones at the outer part were very clear and often in such numbers that not all of them could be accepted as annual. The year-rings on the inner parts of the operculum were hardly visible. This was overcome by photographing the opercula with infra-red plates when these "submerged rings" became quite sharply defined and all the annual rings could be easily distinguished from the discontinuous and interrupted false rings. Roper found also that annual rings could be detected on the operculum in all the very old fish in which scales proved quite useless.

In his study of vertebral variation in teleostean fishes, Ford (1937) gives certain incidental observations on the appearance of "growth-rings" on several parts of the skeleton. He records that the

supra-occipital of *Morone labrax* and *Serranus cabrilla*, the parapophyses of the 2nd to 5th vertebrae of *Mugil*, the posterior parapophyses and expanded base of the first caudal haemal spine in *Labrus bergylta*, the flat bones of the first vertebral segment in the Heterosomata, and certain skull bones in *Zeus faber* all show very clear "growth-rings" or zones. He also remarks that the concave ends of vertebrae showed distinct rings in several forms especially among the elasmobranchs. The parapophyses of haddock and ling, and the skull bones of *Mora* also showed rings. Ford did not determine whether or not those rings were annual, and therefore indicative of age. The rings and zones stood out most clearly in water against a black background.

Hiroaki Aikawa (1937) was the first to follow up Heincke's work with a systematic application of the study of the growth-rings on bones to the determination of age and growth-rate in marine fishes. He used it first with the rings on the vertebral centra of the Japanese chub mackerel, *Scomber japonicus*. His method of measuring the rings was the same as that developed by Freidenfelt for *Lucioperca*. He cut the centrum longitudinally at its middle and measured the rings *in situ* along their radius from the centre of the centrum, as shown in Figure 3. The centra showed numerous rings which "might be thick or thin, complete or incomplete and of varying density"; nevertheless he claimed that the representative annual rings could be recognized by their greater thickness and complete formation. He found that the length of the centrum (evidently meaning the radical length from the centre of the centrum to its outer edge) correlated perfectly with the length of the fish and regarded it as evidence of the validity of the method. He back-calculated from a formula l_n cm. $= K \times r_n$ mm. $\pm k$ where l_n = length to be calculated at age n, K = a correction constant, r_n = the length in mm. of the ring n from the centre of the centrum, and k = another constant which I presume to be the standard deviation of the formula. Several Japanese workers have applied this method to many fishes, especially Scombridae. Michi Uno (1938) working on *Theragra chalcogramma*, and Aikawa and Kato (1938) on *Thunnus orientalis*, *Neothunnus macropterus*, *Germo germo*, *Katsuwonus vagans*, *Seriola quinquiradiata*, *S. aureovittata*, and *Trachurus japonicus* testify to the validity of the method.

Semko (1939) in his study of the Kamchatka pink salmon, examined the scales, the osseous rays of the dorsal and pectoral fins, the maxillae, the operculum, and a few of the vertebrae with a view to determining their utility for age determination. He found that the rays and the maxillae gave no positive results. The rings on the operculum were difficult to distinguish and only the vertebrae showed clear and distinct rings. The scales gave the best and most consistent readings and he strongly recommended their use for the evaluation of age and growth in the pink salmon.

Yasuda (1940 a) made a special study of the variations in the rings on the scale, vertebral centra, and otoliths of the same individual fish, collecting material from *Scombrops chilodipteroides* and *Theragra chalcogramma.* He found that the rings were formed at different periods in scales, otoliths, and vertebrae. The rings on the otoliths were formed three months before spawning, those on the vertebrae only one-and-a-half months before spawning. Yasuda has not tried to correlate the variations between these separate "age indices" with any biological or physico-chemical factors or suggested any cause for the phenomenon.

In a later work Yasuda (1940 b) found that the vertebral centra of *Theragra chalcogramma* showed spawning marks. The spawning mark appears as a partly transparent mark on the margin of the opaque ring near the neural spine. The number of spawning marks corresponds extremely well with the number of spawnings the fish is presumed to have had.

Boyko (1946) gave a short account of the usefulness of the fin ray sections for age determinations of several fishes. He recommended the sectioning of the whole fin after drying. This modified procedure of sectioning the whole fin helped to overcome the difficulty of sectioning individual fragile fin rays. Fins of small fishes below 15 cm. with very fine rays must be embedded in celluloid for easier sectioning. He found that the time factor in collecting, drying, sectioning, and reading the fin rays was the same as with any other age index. "The section must be carefully dried or in some cases heated prior to reading (Salmonidae, Clupeidae, and some other fishes) to make visible the annual rings on the sections. The thickness of the sections (0·4 — 0·5 mm.) is of less importance than a proper selection of the direction of the cut precisely across the fin rays, etc." It was found that the annual rings were formed on both soft and osseous rays. The rings were more clearly expressed on the fin ray sections than on the scales in a majority of the species investigated, namely, *Aspius aspius, Abramis brama, Lucioperca lucioperca, Gadus morrhua, Cyprinus carpio, Blicca bjoerkna, Leuciscus idus, Omorhynchus keta, Salmo salar, Sardinops melanisticta, Caspialosa caspia, C. volgensis, C. pontica, Mugil saliens,* and *M. cephalus.* The numbers of false and indistinct rings on the fin ray sections were far less than on the scales. The fin rays of *Sarda sarda,* with their delicate bases and large internal cavities, showed no annual rings.

Le Cren's work (1947) on the Windermere perch is a fine vindication of the use of bones for age determination. He used mainly the left operculum but occasionally examined the right one as well for comparison. The operculum was removed by inserting a scalpel between the operculum and the sub-operculum and then twisting it. The bone was then pulled out from its articulation with the skull, and after soaking for some time it was dipped into boiling water. It was then cleaned between the fingers and dried. The clarity of the

rings was found to increase with drying and storage. For examination, various lighting arrangements were used, of which the most successful was a vertical projector using polarized light which magnified the image of the bone about five times. The centre of growth, winter rings, and edge of the opercula were plotted on a strip of squared paper from the image thrown on the ground plate of the projector. It was found that with well dried opercula the rings were very clear if examined in reflected light against a dark background, but routine measurements were made in transmitted polarized light. False rings could be distinguished by the abrupt change from the opaque zone to a thin transparent band followed again by an opaque zone. Le Cren differed from Nilsson in fixing the centre of growth for measurement. The operculum has four faces each showing clear rings centred around a small hole and he took as his centre the thickest region of the bone where the holes appeared to meet. He examined scales also from a few fish but found a great prevalence of false rings in them. He has established the validity of age determination by opercula in this perch along three lines of evidence:—

1. Agreement between the modes of length-frequency curves and the mean lengths calculated from the opercular rings.
2. Agreement between the annual increments in the number of the rings and the appearance of successively older age-groups in each year, as determined from length-frequency modes.
3. Observation of a regular annual cycle in the structure of the growing edge of the bone.

In back-calculating, Le Cren found some discrepancies in applying the Lea-Dahl formula. This he held to be due partly to the allometric growth of the bone and the fish, and partly to differential mortality and selective sampling. He observed that the ratio of the opercular length to fish length decreased with length and age of the fish. To reduce the errors caused by the allometry he introduced a regression co-efficient into the formula:— $F_x = F_y \frac{B_x^{0\cdot9202}}{B_y^{0\cdot9202}}$ where B_x is the length of the opercula at age x, F_x is the corresponding length of the fish, B_y is the final length of the operculum, and F_y the final length of the fish. The figure 0·9202 is the regression co-efficient. Logarithmically the formula becomes:—

$$\text{Log. } F_x = \text{log. } F_y + 0\cdot9202 \text{ (log. } B_x - \text{log. } B_y)$$

Le Cren tested the accuracy of his back-calculations by comparison of the mean length of a sample of the population with the means of back-calculated lengths from the samples caught later in the year; secondly, by rearing in aquaria and by marking. These tests showed that the adjusted formula was satisfactory.

Hooper (1949) used the vertebral centra for age analysis of a population of the ameiurid fish, *Schilbeodes mollis*, in the Demming

Lake. He prepared the skeletons "by cutting away part of the skin and muscle from the body and soaking the remaining carcass in a 2 % solution of sodium hypochlorite" for nearly 24 hours and changing the solution every 6 hours; but it was often found to destroy the poorly ossified parts. The vertebral faces were examined under a dissecting microscope. The centra showed a central area of opaque light spots around which were alternating dark, translucent bands and opaque zones. Hooper did not make any measurement of these zones but he found that their numbers fitted quite well with length-groups and age-groups.

Menon (1950) used the supra-occipital crests to determine the age and rate of growth of *Gadus minutus*. The crests were collected by heating the heads of the fish in water from cold to about 80° C. and cleaning the flesh and other tissues off the skull. Through cooking, the bones of the skull became disarticulated and it was easy to pull out the crest from the skull together with the supra-occipital bone. In preparing the crest for reading and measurement, the supra-occipital bone that remained attached to the base of the crest was cut away. The crest was air-dried, when the alternating bands of opaque and transparent regions became clearly visible. Storage in a dry warm place enhanced the clarity of the zones. Bones with fat in them were improved by immersion in a solution of equal parts of benzine and ether for 24 hours. Refrigerated specimens gave as good and clear results as fresh ones. Formalin-preserved specimens were cleaned in fresh water for 24 hours; then they were either stained with alizarine according to the method of Tåning (1944) or the heads were boiled in $2^1/_2$ % caustic soda for 5 minutes. The crest of the formalin-preserved specimens prepared by boiling in caustic soda showed the zones clearly, but very often they were bent and curled and showed the destructive effect of the caustic alkali. In the alizarine-stained crests the opaque broad bands showed lighter staining and rougher surfaces than the transparent zones. Overcooking was found to blur the markings. One opaque zone together with its immediately outlying transparent zone constituted one year's growth. The markings were proved to be annual by observing the period of formation of the zones and by comparing the calculated growth with the size analysis. The opaque zones were laid down chiefly from January to August and the transparent zones from September to November. The age and growth-rate determined from the markings on the supra-occipital crests showed good agreement with the modes of the size-frequency curves. For measuring the supra-occipital crests Menon used a simple vertical projector, the measurements being made on the image of the crest thrown on the screen of the projector. The axis of measurement used is shown in Figure 4. The back-calculations of growth-rate from the crests were done graphically and by using the Lea-Dahl formula. Growth in length of the fish and growth in length of the supra-occipital crest appeared to be directly proportional. The supra-occipital crest

was first observed in the skull when the fish was 1·1 cm. long. This figure of 1·1 cm. (the "pre-supra-occipital-length" of the fish) was introduced into the Lea-Dahl formula for all calculations. The formula used was $L_r = L_R \frac{l_r}{l_R} + 1{\cdot}1$ cm. where L_r is the length of the fish in cm. to be back-calculated, L_R is the length of the fish from which L_r is to be calculated, l_R is the length in mm. of the supra-occipital crest of the fish whose length is L_R cm. and l_r is the length in mm. of the ring r on the crest.

The lengths back-calculated by this formula differed from the empirical lengths by only 0·1 to 0·9 cm. False rings due to "doubling" of the transparent zones were very rare and, whenever present, could be easily detected by their discontinuity.

Discussion.

In spite of all the work that has been done, the causative factor in the formation of rings on the bones is not yet definitely known. Hickling (1933) attributed the formation of the rings on the otoliths of the hake to a physiological rhythm in the fish based on its reproductive cycle. If this is to be accepted as the causative factor in ring formation in the bones also, it will have to be assumed that in some fishes at least, the actual formation of the ring takes place much later than the occurrence of the physiological stress (i.e., of spawning) that causes it. Menon found that the transparent rings on the supra-occipital of *Gadus minutus* were laid down during the latter part of summer and autumn, i.e., many months after spawning. Yasuda has made similar observations on *Scombrops chilodipteroides* and *Theragra chalcogramma*. It may be, of course, that bone growth in a large and relatively slower growing, long-lived fish such as the hake does not follow the same pattern as in *G. minutus*. The causes underlying the formation of rings on certain bones thus remain to be determined, and the usefulness of those rings for age determination has been proved for a few fishes only. Chugunov emphasizes the desirability of examining the bones in all fishes whose growth is being investigated for the first time. It must always be tried in fishes without scales, or where the scales are unreliable and the otoliths thick, massive, or otherwise unsuitable.

Summary.

The following list sets forth in readily available form the various bones that have been used for age determination in different fishes, together with the names of the workers who used them.

Bone Used	Fish	Author
Vertebrae:—		
	Plaice, Turbot, Sole, Haddock and Herring (0, I and II Groups)	Heincke (1904)
	Salmo hucho	Haempel (1910)
	Solea vulgaris	Redeke & Tesch (1912) Thielemann (1916)
	Mackerel	Nilsson (1914)
	Lucioperca	Freidenfelt (1922)
	Lophius piscatorius	Connolly (1922)
	Thunnus thynnus	Sella (1930)
	Mugil, Labrus bergylta, Haddock, Ling, and Elasmobranchs	Ford (1937)
	Scomber japonicus	Aikawa (1937)
	Theragra chalcogramma	Uno (1938)
	Thunnus orientalis, Neothunnus macropterus, Germo germo, Katsuwonus vagans, Seriola quinquiradiata, S. aureovittata, Trachurus japonicus	Aikawa & Kato (1938)
	Oncorhynchus gorbuscha	Semko (1939)
	Schilbeodes mollis	Hooper (1949)
Pectoral Fin Ray:—		
	Acipenser	Holtzmayer (1924) Chugunov (1925) Probatov (1935)
	Silurus glanis	Probatov (1929) Mikhin (1931)
	Lucioperca lucioperca	Klimowa (1935)
	Cyprinus carpio, Carassius auratus, Ctenopharyngodon iddela, Hypophthalmichthys molitrix, Erythroculter erythropterus, Parabramis pekinensis, Pseudaspius leptocephalus, Elopichthys bambusa, Hemibarbus labeo, Leuciscus waleckii, Coregonus ussuriensis, Parasilurus asotus, Brachymystax lenok, Ophicephalus argus	Probatov (1935)
	Oncorhynchus gorbuscha	Semko (1939)
	Aspius aspius, Abramis brama, Lucioperca lucioperca, Gadus morrhua, Cyprinus carpio, Carassius carassius, Pelecus cultratus, Rutilus rutilus, R. frissi, Vimba vimba, Blicca bjoerkna, Leuciscus idus,	

Figure 5.

1. Supra-occipital crest of a female *Gadus minutus* 21·1 cm. (Standard Length). Age 5.
2. Supra-occipital crest of a male *Gadus minutus* 16·1 cm. (S. L.). Age 4.
3. Supra-occipital crest of a male *Gadus minutus* 13·0 cm. (S. L.) Age 2.

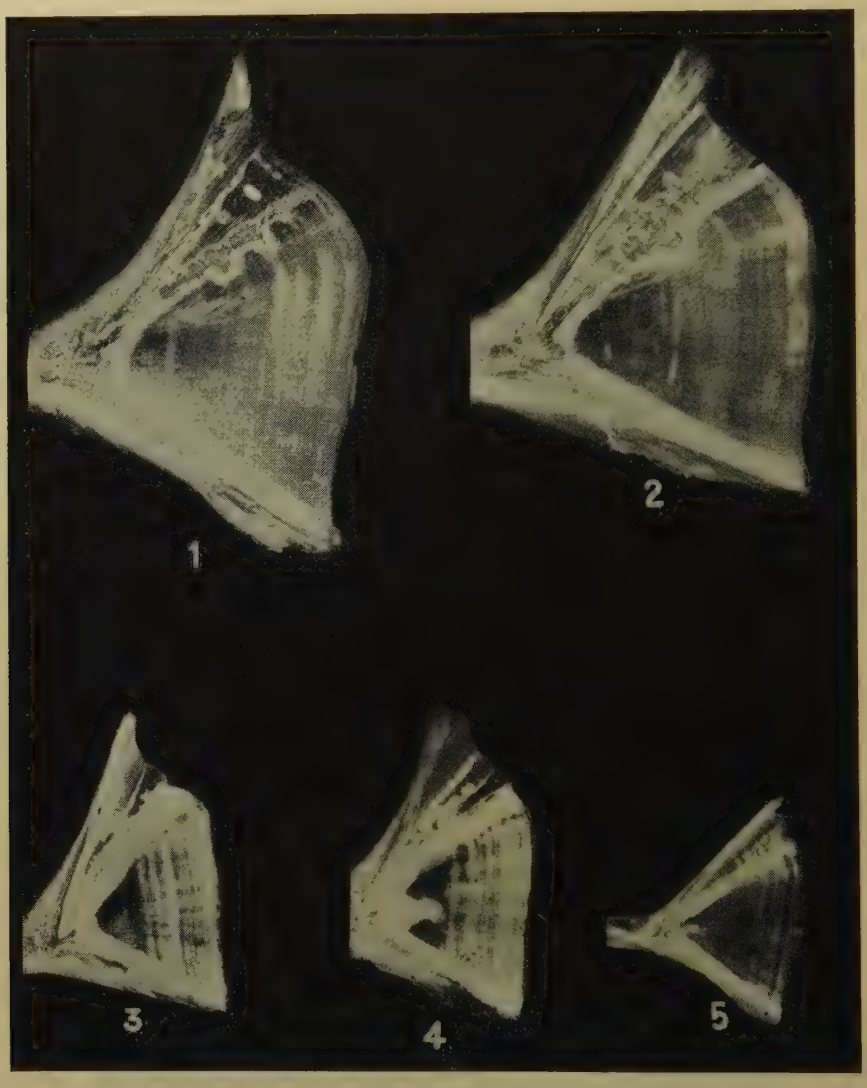


Figure 6.

1. Quadrate of a female *Phycis blennoides* 43·0 cm. (Total Length). Age 10.
2. Quadrate of a female *Phycis blennoides* 42·0 cm. (T. L.). Age 9.
3. Quadrate of a female *Phycis blennoides* 27·5 cm. (T. L.). Age 6.
4. Quadrate of a female *Phycis blennoides* 27·5 cm. (T. L.). Age 6.
5. Quadrate of a male *Phycis blennoides* 24·5 cm. (T. L.). Age 5.

Figure 7.

1. Occipital condyle face of a female *Merluccius merluccius* 82·0 cm. (Total Length). Age 12.
2. Concave face of the vertebral centrum of a female *Phycis blennoides* 43·0 cm. (T. L.). Age 10.
3. Concave face of the vertebral centrum of a female *Phycis blennoides* 42·0 cm. (T. L.). Age 9.
4. Concave face of the vertebral centrum of a female *Phycis blennoides* 27·5 cm. (T. L.). Age 6.
5. Concave face of the vertebral centrum of a male *Phycis blennoides* 24·5 cm. (T. L.). Age 5.

Note:— These untouched photographs cannot give the same degree of legibility attainable in practice by tilting the surface of the bones and altering the lighting.

Bone Used	Fish	Author
Pectoral Fin Ray:—		
	Omorhynchus keta, Salmo salar, Sardinops melanisticta, Caspiclosa caspia, C. volgensis, C. pontica, Mugil saliens, M. cephalus	Boyko (1946)
Dorsal Spine:—		
	Acanthias vulgaris	Kaganowskaia (1933)
Cleithrum:—		
	Rutilus rutilus	Tereschenko (1913)
	Abramis brama	Tereschenko (1917)
	Acipenser sp.	Derjavin (1922)
		Chugunov (1926)
Pectoral Girdle:—		
	Cod (coracoid and scapula)	Heincke (1904)
	Haddock (clavicle)	Heincke (1904)
Operculum:—		
	Salmo hucho	Haempel (1910)
	Perch	Nilsson (1916)
		Svetovedoy's work given by Chugunov (1926)
		Roper (1936)
		Le Cren (1947)
	Roccus lineatus	Scofield (1931)
	Bothus maeoticus	Paspalleff (1934)
	Oncorhynchus gorbuscha	Semko (1939)
	Lucioperca lucioperca	Klimowa (1935)
Skull Bones:—		
	Zeus faber, Mora sp.	Ford (1937)
Supra-Occipital Crest:—		
	Morone labrax, Serranus cabrilla	Ford (1937)
	Gadus minutus	Menon (1950)

Acknowledgements.

My best thanks are due to Mr. F. S. Russell and Mr. Michael Graham for kindly reading through the manuscript of this paper and offering valuable suggestions for its improvement; to Mr. G. A. Steven and Dr. T. J. Hart for much stimulating criticism and help in its preparation; and to Dr. J. S. Alexandrowicz, whose translations from the Russian have been invaluable.

Literature.

Aikawa, Hiroaki. 1937. "Age determination of Chub-Mackerel, *Scomber japonicus* (Houttuyn)." Bull. Japan. Soc. Sci. Fish., Vol. 6, Nos. 1—6, 1937—1938, pp. 9—12.

— 1937. "Notes on the shoal of Bonito along the Pacific coast of Japan." Ibid., Vol. 6, 1937—1938, pp. 13—21.

Aikawa, H., & Kato, M. 1938. "Age determination of fish. I.". Bull. Japan. Soc. Sci. Fish., Vol. 7, 1938, pp. 79—88.

— 1938. "Age determination of Fish. II." Ibid., Vol. 7, 1938, pp. 89—95.

[1]) Arnold, J. 1911. "On the question of the determination of age of the fish." Fish. Courier of Commercial Fisheries.

[2]) [3]) Boyko, E. G. 1946. "Age determination in fishes based on examination of fin ray sections." C. R. (Doklady) Acad. Sci. de l'U. R. S. S., Nouv. Ser., Vol. 53, No. 5, 1946, pp. 483—484.

[2]) Chugunov, N. I. 1925. "On the method of determination of age of sturgeons." Bull. of Fish., 1925, No. 11.

[2]) — 1926. "Determination of age and growth-rate of fishes by bones." Siberian Ichth. Lab. Kerch, 1926, No. 3372.

Connolly, C. J. 1922. "On the development of the angler (*Lophius piscatorius* L)." Contr. Canadian Biol., 1921, Ottawa, 1922, pp. 1—115.

Cunningham, J. T. 1905. "Zones of growth in the skeletal structures of Gadidae and Pleuronectidae." 23rd Ann. Rept. of Fish. Bd. of Scotland, 1905, Part II, Sci. Invest., pp. 125—140.

Dannevig, A. 1933. "On the age and growth of the cod (*Gadus callarias* L.) from the Norwegian Skagerak coast." Rept. Norw. Fish. & Mar. Invest., Vol. 4., No. 1, 1933, pp. 1—145.

Derjavin, A. N. 1922. "Sverioga (*Acipenser stellatus* Pall.). Biological sketch." Bakinsky Ichth. Lab. 1922, Vol. 1.

Ford, E. 1937. "Vertebral variation in teleostean fishes." Journ. Mar. Biol. Assoc., Vol. 22, 1938, pp. 1—60.

Freidenfelt, Av. T. 1922. "Undersökningar över Gösens tillväxt särskilt i Hjälmaren." Medd. Kungl. Lantbrukstyrelsen, Nr. 235 ((Nr. 1, år 1922), pp. 1—75.

Graham, M. 1929. "Studies of Age determination in fish. Part II. A survey of the Literature." Min. Agric. Fish., Fish. Invest., Ser. 2, Vol. 11, No. 3, 1929, pp. 1—50.

Haempel, O. 1910. "Über das Wachstum des Huchens (*Salmo hucho* L.). Ein Beitrag zur Altersbestimmung der Teleosteer." Internat. Rev. Hydrobiol. Hydrogr. 3, 1910—1911, pp. 136—155.

Heincke, Fr. 1904. "Occurrence and distribution of the eggs, larvae and various age-groups of the food fishes in the North Sea." Cons. Perm. Internat. Explor. Mer., Rapp. et Proc. Verb., General Report, 1902—1904, Appendices, Appendix E, pp. 1—39.

— 1908. "Bericht über die Untersuchungen der Biologischen Anstalt auf Helgoland zur Naturgeschichte der Nutzfische." Die Beteiligung Deutschlands an der Internat. Meeresforschung. Jahresb. 4—5, 1908, pp. 67—155.

Hickling, C. F. 1933. "The Natural History of the Hake. IV. Age determination and growth-rate." Min. Agric. Fish., Fish. Invest., Ser. 2, Vol. 13, No. 2, 1933, pp. 1—120.

Holtzmayer, H. 1924. "Zur Altersbestimmung der Acipenseriden." Zool. Anz., 59—60, 1924, pp. 16—18.

Hooper, F. Frank. 1949. "Age analysis of a population of the Ameiurid fish *Schilbeodes mollis* (Hermann)." Copeia, 1949, No. 1, pp. 34—38.

[1]) These papers were not seen by me.

[2]) I am indebted to Mr. Michael Graham for sending me these papers.

[3]) This paper contains only a general statement that these species have been investigated.

Kaganowskaia, S. 1933. "Methods for ascertaining the age and composition of the catch of *Squalus acanthias* L." Bull. of the Far East, Branch of the Acad. of Sci. of U. S. S. R., Nos. 1—2—3, 1933, pp. 5—6.

[1]) Kler, V. O. 1916. "Some data on the determination of age of fish by bone." Fish. Courier, 1916, No. 3.

Klimowa, A. B. von. 1935. "Über den Zander (*Lucioperca lucioperca* Linné) in der Tscholmuga-Bucht des Onega-Sees." Rep. Karelia Sci. Fish. Stat., Vol. 1, Leningrad, 1935, pp. 375—390.

Le Cren, E. D. 1947. "The determination of the age and growth of the perch (*Perca fluviatilis*) from the opercular bone." Journ. Anim. Ecol., Vol. 16, 1947, pp. 188—204.

Menon, M. D. 1950. "The Bionomics of the Poor-Cod (*Gadus minutus* L.) in the Plymouth Area." Journ. Mar. Biol. Assoc., XXIX, (1), pp. 185—239.

Mikhin, V. S. 1931. "Contribution to the knowledge of age and growth of *Silurus glanis* from Aral Sea." Bull. Inst. Ichth., Vol. 12, Fasc. 1, Leningrad, 1931, pp. 259—269.

Monastuirsky, G. N. 1926. "On the technique of determining the rate of growth of fish by measurements of the scales." Collection of papers on Age and Growth determination of fish. Siberian Ichth. Lab. Krasnoyarsk, 1926, pp. 41—79.

Nilsson, D. 1914. "A contribution to the biology of the Mackerel. Investigations in Swedish waters." Cons. Perm. Internat. Explor. Mer., Publ. de Circ., No. 69, 1914, pp. 1—67.

— 1916. "Age and growth of some fresh-water fishes in the Gulf of Bothnia and Lake Mälar." 1916.

Oosten, J. van. 1929. "Life-history of the Lake Herring (*Leucichthys artedi* Le Sueur) of Lake Huron as revealed by its scales with a critique of the scale method." Bull. Bur. Fish., Vol. 44, 1928, Washington, Doc. 1053, 1929, pp. 265—428.

Paspalleff, G. W. 1934. "Beiträge zur Morphologie und Biologie von *Bothus maeoticus* Pall." Arb. aus der Biol. Meeresforsch. am Schwarzen Meer in Varna, Bulgarien, No. 3, 1934, pp. 17—54.

[1]) Probatov, A. N. 1929. "On the age of the cat-fish of Aral Sea." Izvest. Otdiel. Priklad. Ichtiol., 9, Part 2, 1929.

— 1935 a. "Contribution to the study of Kama Sterlet (*Acipenser ruthenus*)." Bull. de l'Inst. des Rech. Biol. de Perm. Liv., 1—2 Tom. 10, 1935, pp. 29—41.

— 1935 b. "On the fresh-water fish of the Amur." Bull. de l'Inst. des Rech. Biol. de Perm. Liv., 1—2 Tom. 10, 1935, pp. 52—64.

Redeke, H. C. & Tesch, J. J. 1912. "Über die wirtschaftliche Bedeutung und die Naturgeschichte der Seezunge (*Solea vulgaris*)." Verhandl. Rijksinst. voor Onderzoek. der Zee, 3, 1911—1912, pp. 3—33.

Roper, K. C. 1936. "Ernährung und Wachstum des Barsches (*Perca fluviatilis* L.) in Gewässern Mecklenburgs und der Mark Brandenburg." Zeitschr. Fisch., Bd. 34, 1936, pp. 567—639.

[1]) Salomon. 1908. Österreich. Fischereizeitung, 1908.

Scofield, E. C. 1931. "The Striped Bass of California (*Roccus lineatus*)." Div. Fish and Game of Calif., Fish. Bull. 29, 1931, pp. 1—82.

Sella, M. 1930. "Distribution and migration of the Tuna (*Thunnus thynnus* L.) studied by the method of hooks and other observations." Internat. Rev. Hydrobiol. u. Hydrogr., Bd. 24, 1930, pp. 446—466.

Semko, R. S. 1939. "The Kamchatka Pink Salmon." Bull. Pacific Sci. Inst. Fish. and Oceanogr., Vol. 16, 1939, Vladivostok, pp. 1—111.

Tåning, Å. V. 1944. "Experiments on meristic and other characters in fishes." Medd. Komm. Danmarks Fisk. og Havunders., Ser. Fiskeri., Bd. 11, 1944, pp. 1—66.

Tereschenko, K. K. 1913. "Voblya (*Rutilus rutilus caspicus* Jack). Its growth and prolificacy." Works of the Astrakhan Ichth. Lab., Vol. 3, Part 2, 1913, pp.1—127.

[1]) These papers were not seen by me.

Tereschenko, K. K. 1917. "La brême (*Abramis brama* L.) de la région du Volga et de la mer Caspienne, son industrie et la biologie." Trav. Lab. Ichth. d'Astrakhan, Vol. 4, Fasc. 2, 1917, pp. 1—159.
Thielemann, V. M. 1916. "Einige Beobachtungen über das Wachstum der Seezunge (*Solea vulgaris* Quensel) und ihr Vorkommen im Nordfriesischen Wattenmeer." Arb. Deutsch. Wiss. Komm. Internat. Meeresf., N. F. 11, Helgoland, 1916, pp. 199—218.
Uno, Michi. 1938. "Age composition of *Theragra chalcogramma* (Pallas). (Preliminary Report II)." Bull. Japan. Soc. Sci. Fish., Vol. 6, 1937—1938, pp. 296—298.
Wundsch, H. H. 1927. "Die Arbeitsmethoden der Fischereibiologie." Handb. der Biol. Arbeitsmethod., Abderhalden, Abt. 9, Teil. 2, II, 1927, pp. 853—1208.
Yasuda, Hideaki. 1940 a. "On the rings formed on scale, vertebral centrum and otolith of the same individual fish, *Scombrops chilodipteroides* and *Theragra chalcogramma* (Pallas)." Bull. Japan. Soc. Sci. Fish., Vol. 8, 1940, pp. 298—300.
— 1940 b. "Spawning marks on the centrum of the vertebral bone of *Theragra chalcogramma* (Pallas)." Bull. Japan. Soc. Sci. Fish., Vol. 9, 1940, pp. 47—48.

APPENDIX

A Note on Growth Zones in Bones of *Phycis blennoides* Brünn.

By

T. J. Hart.

THE work described here was carried out with the object of establishing methods for age determination in a gadoid species in which the more usual methods — scale or otolith readings — are impracticable or unsatisfactory.

Phycis (*Urophycis*) *blennoides* Brünn., the greater forkbeard, is a rather uncommon species, but can be taken in small numbers with fair regularity off Plymouth. Many of the inshore specimens are small and immature, and larger *Phycis* are landed in considerable quantity by the deep-water hake trawlers, but there is some doubt whether all these offshore specimens belong to the same species.

It is hoped that these observations, carried out while I was primarily engaged on other duties, with the kind permission of my director, Dr. N. A. Mackintosh, formerly of "Discovery Investigations", may provide a starting point for any one free to undertake more detailed study of the species, and may also suggest methods of value in the study of other fishes whose ecology is as yet but little known.

The *Phycis* here dealt with were trawled from a soft bottom south and west of Rame Head, less than eight miles off-shore, in May and June 1949. It was quite evident that these inshore specimens belonged only to one species which I take to be *P. blennoides* Brünn. I had frequently met with it in small numbers throughout the winter in

other trawlings near Plymouth, and latterly it has tended to increase in numbers in this area, though never abundant. My preliminary findings strongly suggest that it is a fish of slow growth, so that the increase due to the rest given to the trawling grounds by the war years may quite probably only just be becoming apparent.

This fish has large scales, but they are exceedingly deciduous, and so many get rubbed off in the trawl that it is quite impossible to be sure of getting scales from the same region of the body of any two consecutive specimens. The otoliths are massive, lobulated, and brittle, and though it is possible to make out rings after sectioning them by grinding, the method is too slow to be of much value for biometric work. Moreover, even when good sections were achieved, the ringing seemed very irregular.

I therefore turned my attention to other skeletal structures that have been found to afford indices of age in fishes, and examined the growth-zones or rings on the flattened bones of the operculum and the vertebral centra. A few observations were also made on the same bones in small hake (*Merlucius merluccius*), pollack (*Gadus pollachius*), and whiting (*G. merlangus*), to see how far the methods adopted for *Phycis* seemed generally applicable for age determination in the Anacanthini.

The specimens were measured, sexed, gutted, and beheaded on the day of capture. The heads were cut off just behind the level of the pectoral fins so that some 4 or 5 of the anterior thoracic vertebrae were included. Sometimes when catches were large the heads were stored overnight in a refrigerator. Subsequent treatment followed the methods described in detail by M e n o n — the heads were cooked to about 80° C. (large heads required actual boiling) — and the flesh removed from the bones with fingers, forceps, and a jet of water. Soaking in some fat-solvent followed by dry storage in labelled boxes left most of them in excellent condition. Xylol appeared to be the best of the fat-solvents tried, though slow, and was an excellent medium in which to examine the bones. Prolonged storage, up to a month or more in xylol, has done no harm and even seems to have increased the legibility of bones as thin as the inter-opercula of pollack. It was also good for vertebrae of the same species. I examined the bones in xylol on a black background under the lowest power of a binocular dissecting microscope, and took rough measurements direct with an eyepiece micrometer.

The rather small thick vertebrae of *Phycis,* with their centra forming comparatively shallow concavities, were at times too dense to be read directly with confidence. I found that this difficulty could almost entirely be overcome by crudely dissecting away the centrum from the rest of the bone. It was necessary to have a few vertebrae in reserve, for some are inevitably spoilt when this process is conducted at speed, but it was found that the first few vertebrae behind the atlas always agreed in the number of their rings, so that for age reading

only (not, of course, for measurement or back-calculation) it did not matter which was taken. The method was to trim off projections and cut the vertebra in half with scissors, and then pare away the comparatively spongy bone from the back of the centrum with the small blade of a good knife. With a little practice this process became surprisingly easy and rapid.

The measurement of concave surfaces such as those of vertebral centra is not easy, and for purposes of back-calculation one should work on flat bones whenever possible, but in almost all the fishes I have so far examined, the vertebrae may profitably be used to confirm the other readings. The flattened bone which shows the zonations best in *Phycis* is the small triangular quadrate. As in several other Gadidae, this forms a characteristic diamond-shaped complex with the jugal, and the two are easily found on the boiled heads after pulling away the pre-opercula and the muscle lying immediately beneath it. The age indices on the quadrates are by no means ideal, the first zone is often ill defined and a certain amount of doubling and "false-ringing" occurs. The later growth of the oldest fishes also is often hard to distinguish. However, these draw-backs also occur, to a greater or less degree, with every other "age-indicator" of fishes so far studied, whether scales, otoliths, or bones. Whenever I found it possible to read the quadrates with confidence the vertebral rings were in agreement with them, and I suggest that it is justifiable practice with such a fish as *Phycis* to regard the vertebral reading as the critical one for determination of age, and to allow this reading to decide on cases of double ringing in the quadrates. The quadrates can be measured satisfactorily from the apex along an axis normal to the plane of the zones; this axis does not bisect the angle of the apex, but coincides most nearly with the straightest of the very faint curved striae which can usually be seen to radiate from the centre of growth. In making the measurements the vertebral readings were allowed to influence my judgement of doubtful zonings in the quadrates, but I think it must be admitted that the figures obtained are sufficiently consistent to justify this procedure. The results are shown in the table on pp. 338—39.

If the zones should be shown later to be annual, then *Phycis blennoides* Brünn. is a slow-growing fish, the length increments over the main growing period varying a little between 2 and 3·5 cm. per annum. There is a marked discrepancy in size between the sexes, the males being smaller, and apparently more slow-growing than are the females though it is unlikely that they live so long.

The experiments with various bones of other small Gadidae showed that the vertebral centra give exceptionally clear rings in young pollack (*G. pollachius*) and whiting (*G. merlangus*). In pollack the thin flat inter-operculars also seem very promising, provided that a suitable axis of measurement for the zones could be fixed.

I had hoped that with hake also one of the opercular bones might

Table 1.
Age Determinations of *Phycis blennoides*
Age Readings

I. Males.

Length of Fish cm.	From Vertebrae Age-Group	Comment	From Quadrates Age-Group	Distance of outer Margin of Bands from Apex, Micro-divisions 1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	Comment
24·0	IV	Good	IV	3·8	4·4	5·3	6·0	—	—	—	—	—	—	Good
23·0	IV	Good	IV	3·0	3·8	4·2	5·1	—	—	—	—	—	—	Some doubling
22·5	III	Fair	III	4·0	4·5	5·0	—	—	—	—	—	—	—	Fair? 1st zone missed in both
32.5	VIII	Fair	VIII	3·6	4·6	5·2	6·0	6·6	7·2	7·8	8·4	—	—	Fair, outer zone marginal
26·0	VI	Fair	VI	3·2	3·8	4·5	4·9	5·3	5·7	—	—	—	—	Good on one
24·0	VI	Good	VI	3·5	4·0	4·4	4·9	5·3	5·7	—	—	—	—	Fair
22·5	IV?	Difficult	IV	3·4	3·9	4·8	5·4	—	—	—	—	—	—	Fair
21·5	IV	Good	III+	3·0	3·6	4·1	?4·7	—	—	—	—	—	—	Good, wide opaque margin
24·0	IV	Good	IV	3·0	3·6	4·2	4·9	—	—	—	—	—	—	Fair
24·5	IV	Fair	IV	3·4	4·5	5·0	5·5	—	—	—	—	—	—	Good
23·5	IV	Good	IV	3·0	3·5	4·2	5·3	—	—	—	—	—	—	Fair
24·0	—	—	V	3·5	4·0	4·5	5·0	5·5	—	—	—	—	—	Good
24·5	V	Fair	V	3·0	4·0	4·5	5·2	6·0	—	—	—	—	—	Good, outer zone marginal
23·5	V	Good when cut	V	3·5	3·9	4·4	4·8	5·4	—	—	—	—	—	Good, outer zone marginal
25·5	V	Good when cut	IV?	3·5	4·2	5·0	6·0	—	—	—	—	—	—	Bad? at least 1 year missing
23·5	V	Fair	V	3·3	3·8	4·4	5·0	5·5	—	—	—	—	—	Good, outer zone marginal
23·5	V	Fair	V	3·5	3·8	4·1	4·5	5·0	—	—	—	—	—	Fair, 1st zone very faint
24·5	VI?	Bad	VI	3·5	4·0	4·5	5·2	5·7	?6·5	—	—	—	—	Fair, outer zone marginal
27·5	VII	Good	VII	3·4	3·9	4·6	5·1	5·7	6·3	6·8	—	—	—	Good, outer zone marginal

II. Females.

42·0	IX	Fair	IX	—	—	—	—	—	—	—	—	—	—	Fair
25·5	V	Fair	V	3·9	4·6	5·2	5·8	6·4	—	—	—	—	—	Good
23·5	IV	Good	IV	—	—	—	—	—	—	—	—	—	—	Fair

35·0	IX	Fair	IX	—	—	—	—	—	—	—	—	—	—	Fair
24·5	IV	Fair	IV	3·3	4·0	4·5	5·3	—	—	—	—	—	—	Good
36·0	X	Good	X	3·6	4·0	4·5	5·0	5·5	6·2	6·9	7·5	8·0	8·7	Good
23·5	IV	Good	IV	4·0	4·7	5·2	5·8	—	—	—	—	—	—	Good
24·0	IV	Good	IV	3·6	4·2	4·9	5·7	—	—	—	—	—	—	Good
24·5	IV	Fair	IV	3·6	4·2	4·8	5·8	—	—	—	—	—	—	Fair, some doubling
25·0	V	Good	V	3·5	4·0	4·3	4·7	5·6	—	—	—	—	—	Fair, outer zone marginal
24·5	V	Fair	V	3·5	4·4	5·0	5·6	6·3	—	—	—	—	—	Good, outer zone marginal
25·0	V	Good	V	3·5	4·4	4·8	5·3	6·0	—	—	—	—	—	Fair, densely opaque at margin
38·0	IX?	Bad	X	3·6	4·4	5·0	5·6	6·3	7·0	7·6	8·4	9·2	9·6	Difficult, opaque at margin
28·5	VI	Good when cut	VI	4·0	4·5	5·0	6·0	6·5	7·0	—	—	—	—	Fair
25·5	V	Good when cut	V	3·0	3·9	4·3	4·7	5·3	—	—	—	—	—	Fair
39·5	X	Good when cut	X	3·6	4·1	4·8	5·4	6·0	7·0	7·5	8·0	9·2	10·0	Fair
25·0	IV?	Doubling	IV?	3·0	4·2	4·6	5·4	—	—	—	—	—	—	Doubling
37·0	IX?	Difficult	X	3·4	4·5	5·2	5·8	6·5	7·1	7·6	8·3	9·0	9·6	Fair
29·0	VI	Fair	VI	4·1	4·7	5·1	5·7	6·1	6·5	—	—	—	—	Good
27·0	V	Difficult	V	3·8	4·7	5·4	5·8	6·2	—	—	—	—	—	Good
43·5	IX?	Difficult	VIII?	4·0	4·8	5·8	7·0	7·7	8·2	9·7	10·5	—	—	Very doubtful readings doubling?
39·5	VIII?	Difficult	VIII?	3·5	4·5	5·4	6·0	7·0	7·8	8·4	9·1	—	—	Doubling, bad
27·5	V	Fair	V	3·9	4·5	5·1	5·8	6·3	—	—	—	—	—	Good
38·5	VIII	Fair	VIII	—	—	—	—	—	—	—	—	—	—	Bad diffuse coupling of outer opaque zones
40·0	IX	Good when cut	IX	—	—	—	—	—	—	—	—	—	—	Fair, early zones faint, outer opaque
38·0	X	Fair	X	3·5	4·2	5·2	6·0	7·0	7·5	8·0	8·6	9·2	9·8	Good
40·0	VIII	Good when cut	VIII	3·5	4·3	4·8	5·5	6·5	7·5	8·5	9·8	—	—	Fair, outer zone marginal
24·0	IV	Fair	IV	3·5	4·1	4·8	5·5	—	—	—	—	—	—	Good
27·5	VI	Fair	VI	3·5	4·1	4·6	5·3	6·0	6·8	—	—	—	—	Good, 1st zone faint, outer marginal
25·0	IV	Fair	IV	3·1	3·7	4·4	5·3	—	—	—	—	—	—	Good
27·5	VI	Good	VI	3·2	4·0	4·5	5·0	5·6	6·0	—	—	—	—	Good
27·5	VI	Fair	VI	3·1	3·6	4·2	5·0	5·7	6·3	—	—	—	—	Good

be utilized, but only the inter-opercular showed promise, and even these proved too thin and leaf-like for satisfactory interpretation, tending to become ridged and to curl at the edges so that the zonations were obscured. Vertebrae proved moderately useful, but suggested slower growth-rate than is generally accepted for this species on the basis of otolith readings. It must be pointed out, however, that I was dealing only with the small immature "Channel hake" that have only recolonized the local inshore grounds since the war, and these are likely to grow more slowly than the main stock of the species inhabiting deeper, probably richer, water farther westward. I was certainly able to obtain good readings more often from vertebrae than from the otoliths.

Salmon of the River Shannon in 1946 and 1947.

By

Arthur E. J. Went,

Department of Agriculture, Dublin.

1. Introduction.

The changes in the River Shannon wrought by the hydro-electric development of the river have produced marked changes in the stocks of salmon. It has been shown previously (W e n t, 1943 and 1946) that the larger fish have been eliminated from the stocks. As explained elsewhere, the actual numbers of fish entering the river are known (see W e n t, 1943) and since 1941 the daily runs of fish into the river have been carefully recorded. Comparable numbers of different year-classes, age-groups, etc. can be calculated.

During the years 1946 and 1947 further material was collected from the salmon stocks of this river and before discussing the relative numbers involved in the different groups of fish, a detailed analysis of the incoming populations of salmon in these years will be given. The nomenclature adopted in this paper has already been described (W e n t, 1946).

2. Material and analysis.

About 50 scales were scraped off each fish from the region of the body between the lateral line and the dorsal fin; these scales were preserved dry in special envelopes. The weight and length of the fish from the tip of the snout to the fork of the tail were also recorded, together with the date of capture. A single typical scale was selected from each set of scales, cleaned in dilute sodium peroxide solution, and mounted by means of gelatine solution on a microscope slide. In this way satisfactory scales from 880 and 965 fish were obtained, respectively, from the years 1946 and 1947. The mounted scales were examined microscopically and the age recorded.

There were some fluctuations in the proportion of fish sampled throughout the season but their effects were eliminated, with the aid of the catch figures, by suitable arithmetical adjustments. Certain adjustments were also necessary for the short periods when the fishing weir was out of commission. Throughout the tables the weighted figures have been used wherever possible.

Table 1. Percentage of each smolt age in each age-group.

Smolt class	Age-groups (in winters) 1+	2	2+	3	3+	4	With SM's	Total maiden fish
				1946				
1	11·4	19·0	24·4	34·4	100·0	—	21·0	13·5
2	84·8	77·2	70·0	65·6	—	100·0	75·0	82·7
3	3·8	3·8	5·6	—	—	—	4·0	3·8
Total	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Average age of smolts[1]) ..	1·92	1·85	1·81	1·66	1·0	2·0	1·83	1·90
				1947				
1	15·7	18·3	23·2	40·0	—	—	8·6	16·5
2	73·7	75·4	76·8	60·0	100·0	100·0	88·6	73·9
3	10·4	6·3	—	—	—	—	2·8	9·4
4	0·2	—	—	—	—	—	—	0·2
Total	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0
Average age of smolts[1]) ..	1·95	1·88	1·76	1·6	2·0	2·0	1·94	1·93

[1]) Based on the assumption that a complete year or multiple thereof was spent in fresh water before migration as a smolt.

Smolt ages. Table 1 gives the distribution of the various smolt classes in the different age-groups in 1946 and 1947. The proportion of one-year smolts and the average age of the smolts were somewhat higher in 1946 and 1947 than those recorded for the previous two years (W e n t, 1946). One-year smolts increased in proportion, and the average age of the smolt decreased, as the age-groups were ascended. Such differences as occurred between the proportion of the different smolt classes in the years 1941 and 1944—47, inclusive, are such as one would have expected in a fishery unaffected by man's activities, and there is no reason in this respect to suggest that the stocks of salmon in the Shannon are in a transitionary stage. The one-year smolts showed no regular changes in their proportions in the different age-groups as the season progressed (Table 2).

Table 2. Percentage of one-year smolts in each month in the more important age-groups.

	1946 Age-groups (in winters) 1+	2	2+	Total for maiden fish	1947 Age-groups (in winters) 1+	2	Total for maiden fish
Feb./Mar.	—	12·5	—	21·8	—	*6·6*	10·5
April	—	21·8	13·3	20·5	—	23·0	24·2
May	4·5	22·7	25·8	19·0	*20·0*	11·3	15·7
June	10·1	—	*28·4*	10·3	16·4	*33·3*	16·6
July	14·5	0	*50·0*	14·5	13·4	—	13·4
Total	11·4	19·0	24·4	13·5	15·7	18·3	16·5

Figures in italics derived from small numbers of observations.

Table 3. Estimated proportion (%) of the different smolt types in each smolt class (maiden fish only).

Smolt age	1946 Type A	1946 Type B	1947 Type A	1947 Type B
One year .	—	13·5 (133)	—	16·5 (158)
Two years .	14·2 (118)	68·5 (569)	14·7 (137)	59·2 (550)
Three years	3·2 (28)	0·6 (5)	6·0 (54)	3·4 (30)
Four years.	—	—	—	0·2 (1)
Total	17·4 (146)	82·6 (707)	20·7 (191)	79·3 (739)

Figures in brackets indicate number of fish examined. The percentages are derived from the weighted figures.

Smolt types. In previous contributions to the study of the biology of Irish salmon two smolt types have been described (W e n t, 1938, 1943, and 1946). Some fish showed marked growth in fresh water before migrating to the sea as smolts (type B smolts) whereas others showed no such growth (type A smolts). In the present material the same two groups could be observed and the division into the two smolt types in the different smolt classes has been indicated in Table 3.

Age-groups. Salmon of the River Shannon may be divided into six groups of maiden or unspawned fish and one other heterogeneous group, having only one common property, namely, the presence of one or more spawning marks on their scales. (Table 4). In each year, as for the years described previously, the bulk of the fish were grilse (1+ winters) and the small spring fish (2 winters) were second in importance. In 1946 and 1947, 61·4 % and 44·2 %, respectively, of the total incoming populations were grilse taken in the month of June. Up to

Table 4. Estimated monthly catch in each age-group as percentage of the yearly total.

Month	Age-group (in winters) 1+	2	2+	3	3+	4	with SM's	Total
			1946					
Feb./March	—	3·3	—	1·3	—	+	0·4	5·0
April	—	5·3	0·8	0·4	—	—	0·2	6·7
May	2·0	2·0	3·0	—	+	—	0·1	7·1
June	61·4	—	1·6	—	—	—	1·8	64·8
July	15·8	0·1	0·1	—	—	—	0·4	16·4
Total	79·2	10·7	5·5	1·7	+	+	2·9	100·0
			1947					
Feb./March	—	4·6	—	0·6	—	0·3	0·6	6·1
April	—	5·2	0·4	0·7	0·1	—	0·4	6·8
May	0·9	3·4	1·3	0·2	—	—	0·1	5·9
June	44·2	0·5	0·5	0·1	—	—	0·4	45·7
July	32·0	—	—	—	—	—	3·5	35·5
Total	77·1	13·7	2·2	1·6	0·1	0·3	5·0	100·0

+ less than 0·05 %.

Table 5. Percentage of each age-group in the catch of each month.

Month	Age-group (in winters) 1+	2	2+	3	3+	4	with SM's	Total
			1946					
Feb./March	—	66·0	—	25·8	—	1·0	7·2	100
April	—	79·0	11·8	5·5	—	—	3·2	100
May	28·5	27·8	41·8	—	0·6	—	1·3	100
June	94·7	—	2·5	—	—	—	2·8	100
July	96·4	0·4[1])	0·9	—	—	—	2·3	100
Total	79·2	10·7	5·5	1·7	+	+	2·9	100
			1947					
Feb./March	—	76·2	—	9·5	—	4·8	9·5	100
April	—	77·5	5·4	10·9	0·8	—	5·4	100
May	16·3	57·7	21·7	3·2	—	—	1·1	100
June	96·7	1·1	1·1	0·1	—	—	0·9	100
July	90·0	—	—	—	—	—	10·0	100
Total	77·1	13·7	2·2	1·6	0·1	0·3	5·0	100

[1]) One fish with heavily eroded scales less than 0·05 %.

and including the month of April small spring fish were predominant in the catches (Table 5). In 1946 small summer fish (2+ winters) predominated in May, but in the following year the small spring fish were most important. In June and July of both years the grilse formed 90 % or over of the total incoming populations. The bulk of the grilse were taken in each year in the month of June, although in 1947 the proportion running in July was greater than recorded in the three previous years (see also W e n t, 1946, and Table 6). The greatest

Table 6. Percentage of total of each age-group in each month.

Month	Age-group (in winters) 1+	2	2+	3	3+	4	with SM's	Total
			1946					
Feb./March	—	31·0	—	76·5	—	100	12·3	5·0
April	—	49·7	14·5	23·5	—	—	7·0	6·7
May	2·5	18·4	54·6	—	100	—	3·5	7·1
June	77·5	—	29·1	—	—	—	63·1	64·8
July	20·0	0·9	1·8	—	—	—	14·1	16·4
Total	100	100	100	100	100	100	100	100
			1947					
Feb./March	—	33·6	—	37·5	—	100	12·0	6·1
April	—	38·0	18·2	43·7	100	—	8·0	6·8
May	1·2	24·8	59·7	12·5	—	—	2·0	5·9
June	57·2	3·6	22·7	6·3	—	—	8·0	45·7
July	41·6	—	—	—	—	—	70·0	35·5
Total	100	100	100	100	100	100	100	100

Table 7. Proportion of spring and summer fish in the different months of the season.

Month	1946		1947	
	Spring fish	Summer fish	Spring fish	Summer fish
Feb./March	100·0	—	100·0	—
April	88·2	11·8	93·8	6·2
May	71·6	28·4	62·0	38·0
June	—	100·0	1·3	98·7
July	0·4[1])	99·6	—	100·0
Total	12·9	87·1	16·7	83·3

[1]) One fish only, probably a "dropper", i.e., a fish which has ascended the river earlier and dropped back into the tideway, reascending the river again on a second occasion.

numbers of small spring fish ran in April in both years, and of large spring fish in February/March 1946 and April 1947. Prolonged extremely cold weather may have, in fact, been responsible for the somewhat later runs of large spring fish in 1947. Small summer fish ran in greatest numbers in May of both years. More previous spawners ran in June than in any other month in 1946 and in July in 1947. Late runs of previous spawners might have been expected in a grilse river. Up to the end of March all the fish entering the river were spring fish, a small proportion of summer fish ran in April, in May the proportion of summer fish increased somewhat but still remained below that of the spring fish, and thereafter summer fish predominated (Table 7).

Visual observations of the proportion of grilse (based mainly on the size) made by the employees of the Shannon Fisheries at Limerick in 1946 and 1947 gave figures of 78·8 % and 79·4 %, respectively. These figures agree quite closely with the figures given in Table 5 when it is realized that identification of grilse solely on the basis of size is somewhat inaccurate, as diminutive small spring and summer fish are sometimes reckoned as grilse, and large grilse are conversely reckoned with the two groups, small spring and summer fish, which cannot be distinguished one from another by external appearances.

Table 8. Absence habit of previous spawners.

Absence habit	1946				1947		
	Age at first spawning in winters			Total	Age at first spawning in winters		Total
	1+	2	2+		1+	2	
Short	13	—	—	13	25	—	25
Long	—	2	3	11[1])	—	5	10[1])
Very long	2	—	—	2	—	—	—
Total	15	2	3	26	25	5	35

[1]) Including fish the age of first spawning of which could not be determined.

Table 9. Percentage composition by weight.

Year	Age-group in winters 1+	2	2+	3	3+	4	With SM's	Total
1946	65·3	15·0	8·3	5·7	0·2	0·2	5·3	100
1947	64·4	20·1	3·5	4·8	0·3	1·0	5·9	100

Previous spawners, consisting of a heterogeneous group of fish having only one common property, namely, the presence of spawning marks on their scales, can be classified (1) on the age at first spawning and (2) the absence habit, or time spent feeding in the sea between what would have been, but for the intervention of man, two successive spawnings. In Table 8 the previous spawners have been so classified. Spring fish returned after a long absence habit (a full year feeding

Table 10. Divided migration and return.

A table showing the years in which the fish were hatched (Percentages of the total runs).

Returned in 1946 as:—	Hatched in the year 1939	1940	1941	1942	1943	1944	Total
Grilse (1 + winters)	—	—	—	3·0	67·0	9·2	79·2
Small spring fish ..... (2 winters)	—	—	2·0	8·3	0·4	—	10·7
Small summer fish ..... (2 + winters)	—	—	1·3	3·9	0·3	—	5·5
Large spring fish ..... (3 winters)	—	—	0·6	1·1	—	—	1·7
Large summer fish ..... (3 + winters)	—	—	—	+	—	—	+
Very large spring fish .... (4 winters)	—	—	+	—	—	—	+
Previous spawners ..... (with SM's)	0·3	0·6	0·2	1·7	0·1	—	2·9
Total	0·3	0·6	4·1	18·0	67·8	9·2	100·0

Returned in 1947 as:—	Hatched in the year 1939	1940	1941	1942	1943	1944	1945	Total
Grilse (1 + winters)	—	—	—	0·2	8·1	56·7	12·1	77·1
Small spring fish ..... (2 winters)	—	—	—	0·9	10·3	2·5	—	13·7
Small summer fish ..... (2 + winters)	—	—	—	—	1·7	0·5	—	2·2
Large spring fish ..... (3 winters)	—	—	—	1·0	0·6	—	—	1·6
Large summer fish ..... (3 + winters)	—	—	—	0·1	—	—	—	0·1
Very large spring fish .... (4 winters)	—	—	0·3	—	—	—	—	0·3
Previous spawners ..... (with SM's)	0·3	—	0·7	0·4	3·6	—	—	5·0
Total	0·3	—	1·0	2·6	24·3	59·7	12·1	100·0

+ less than 0·05 %.

in the sea between spawnings) and summer fish after a short (less than a full year) or very long (more than a full year) absence habit. These results are, of course, in conformity with the results obtained previously.

Small spring fish and the higher age-groups were more important commercially than their proportion in the catch would indicate. In Table 9 the proportion of the different age-groups by weight are given for each year, and it will be noted that the proportion of grilse by weight is only about 65 % of the total.

Divided migration and return. Table 10 gives the years in which the fish were hatched and it will be seen that in both 1946 and 1947 one year-class (3-year olds) accounted for 2½ times the number of fish in the next most important year-class. In each year six year-classes took part in the formation of the stocks of fish.

Size distribution. In both 1946 and 1947, over 80 % of the fish had lengths below 27·95 inches (Table 11), the proportion being somewhat lower than in 1941 (W e n t, 1943) and 1945 (W e n t, 1946).

Table 11. Estimated size distribution in the different age-groups as percentages of the total catch in 1946 and 1947.

Class Interval[1])	Age-group (in winters) 1+	2	2+	3	3+	4	with SM's	Total
				1946				
20	2·6	—	—	—	—	—	—	2·6
22	25·0	0·1	—	—	—	—	—	25·1
24	37·9	0·3	0·1	—	—	—	0·8	39·1
26	11·1	1·6	0·8	—	—	—	0·4	13·9
28	2·6	4·4	2.0	—	—	—	0·3	9·3
30	—	3·0	1·4	—	—	—	0·6	5·0
32	—	0·6	0·8	—	—	—	0·2	1·6
34	—	0·6	0·3	0·4	—	—	0·2	1·5
36	—	0·1	0·1	0·6	—	—	0·1	0·9
38	—	—	—	0·3	+	—	0·2	0·5
40	—	—	—	0·2	—	+	0·1	0·3
42	—	—	—	0·2	—	+	—	0·2
Total	79·2	10·7	5·5	1·7	+	+	2·9	100·0
				1947				
20	1·8	—	—	—	—	—	—	1·8
22	19·1	—	—	—	—	—	0·5	19·6
24	38·8	0·1	—	—	—	—	1·7	40·6
26	15·1	1·2	—	—	—	—	1·4	17·7
28	2·1	5·7	0·6	—	—	—	0·3	8·7
30	0·2	4·2	1·0	—	—	—	—	5·4
32	—	2·0	0·3	0·2	—	—	0·3	2·8
34	—	0·4	0·2	0·3	—	—	0·6	1·5
36	—	0·1	0·1	0·4	—	—	0·2	0·8
38	—	—	—	0·3	—	—	—	0·3
40	—	—	—	0·2	0·1	0·3	—	0·6
42	—	—	—	0·2	—	—	—	0·2
Total	77·1	13·7	2·2	1·6	0·1	0·3	5·0	100·0

[1]) Class interval 20 etc. includes all fish with lengths between 19·95 and 20·95 inches etc.

Proportion of the Sexes. The determination of the sex of a salmon by external examination is not entirely satisfactory when one is dealing with clean fresh-run fish. The results given in Table 12 are, therefore, not entirely reliable. They probably do, however, indicate the general relationship between the two sexes in the different age-groups. In the maiden fish there appears to be a tendency for the small spring fish to have a larger proportion of females than in the other age-groups.

Table 12. Percentage of females as determined by visual observation in the different age-groups.

Year	Age-groups (in winters)						Total maiden fish
	1+	2	2+	3	3+	4	
1946	57	67	53	26	100	0	57
1947	58	65	55	25	0	0	59

Average sizes. The average weights and lengths in the various smolt classes in 1946 and 1947 will be found in Table 13, to which the following details are added:—

(1) Grilse (1+ winters)

	1946 Number examined = 519			1947 Number examined = 692		
	lb.	inches	Date of capture	lb.	inches	Date of capture
Minimum	3·25	20·9	4. June	4·01[1])	20·6	5. July
Mean	6·0	24·8	—	6·6	24·9	—
				11·75	29·1	16. June
Maximum	10·5	29·4	18. July	11·5	30·4	6. June

[1]) 13 other fish of the same weight with lengths between 20·6 and 24·0 inches were also recorded.

(2) Small spring fish (2 winters)

	1946 Number examined = 210			1947 Number examined = 175		
	lb.	inches	Date of capture	lb.	inches	Date of capture
Minimum	5·0	23·8	25. February	6·0	25·2	20. May
Mean	10·2	29·6	—	11·6	30·3	—
Maximum	21·0	36·0	27. February	20·0	36·3	9. April

(3) Small summer fish (2+ winters).

	1946 Number examined = 90			1947 Number examined = 33		
	lb.	inches	Date of capture	lb.	inches	Date of capture
Minimum	7·0	25·0	3. May	8·0	28·3	24. May
Mean	11·0	29·9	—	12·4	31·1	—
Maximum	18·0	36·0	17. May	20·8	36·0	20. May

Table 13. Mean weights and lengths in the various age-groups and smolt classes in 1946 and 1947.

Grilse (1+ winters).

Smolt age:	1			2			3		
	lb.	ins.	K.	lb.	ins.	K.	lb.	ins.	K.
				1946					
May	6·8	24·8	1·20	5·7	24·1	1·12	6·4	24·9	1·15
June	6·4	26·1	1·17	5·9	24·3	1·15	6·0	23·8	1·23
July	6·4	24·9	1·10	6·1	25·6	1·14	6·2	24·4	1·15
Total	6·4	25·3	1·14	6·0	24·8	1·14	6·1	24·1	1·20
				1947					
May	6·3	25·0	1·12	6·2	24·9	1·11	—	—	—
June	6·6	24·8	1·20	6·5	24·8	1·18	7·0	25·7	1·15
July	6·1	24·3	1·18	6·5	24·9	1·17	7·4	25·7	1·21
Total	6·5	24·7	1·19	6·5	24·9	1·17	7·1	25·7	1·16

Total

	1946			1947		
	lb.	ins.	K.	lb.	ins.	K.
May	5·9	24·2	1·13	6·3	25·0	1·12
June	6·0	24·4	1·16	6·6	24·9	1·19
July	6·2	25·6	1·13	6·5	24·9	1·17
Total	6·0	24·8	1·15	6·6	24·9	1·17

Small spring fish (2 winters).

Smolt age:	1			2			3		
	lb.	ins.	K.	lb.	ins.	K.	lb.	ins.	K.
				1946					
Feb./Mar. .	10·2	29·4	1·10	10·1	29·7	1·09	10·0	30·6	0·97
April	10·5	29·6	1·13	10·2	30·0	1·09	8·5	27·4	1·13
May	11·5	30·3	1·14	10·1	28·9	1·11	8·5	28·6	1·01
July	—	—	—	9·5	31·0	0·88	—	—	—
Total	10·7	29·7	1·13	10·1	29·7	1·10	8·9	28·6	1·05
				1947					
Feb./Mar. .	10·0	28·8	1·16	10·4	29·3	1·15	14·5	32·6	1·16
April	12·4	30·5	1·22	12·0	30·1	1·23	11·4	30·1	1·16
May	10·6	29·4	1·16	10·9	29·9	1·13	11·8	30·6	1·15
June	10·1	29·6	1·08	12·8	31·7	1·12	—	—	—
Total	11·8	30·1	1·20	11·5	30·0	1·18	12·0	30·8	1·14

Total

	1946			1947		
	lb.	ins.	K.	lb.	ins.	K.
Feb./Mar. .	10·1	29·7	1·06	10·8	29·6	1·12
April	10·2	29·9	1·10	12·1	30·2	1·22
May	10·3	29·2	1·13	10·9	29·9	1·13
July (June)	9·5	31·0	0·88	11·9	31·0	1·11
Total	10·2	29·6	1·10	11·6	30·3	1·16

Tab. 13 cont. **Small summer fish** (2+ winters).

Smolt age:	1 lb.	1 ins.	1 K.	2 lb.	2 ins.	2 K.	3 lb.	3 ins.	3 K.
				1946					
April	9·8	29·4	1·06	12·0	30·7	1·13	9·8	29·4	1·06
May	12·2	30·6	1·14	10·5	29·3	1·10	11·8	31·0	1·10
June	12·3	31·1	1·14	9·4	29·2	1·06	12·0	32·1	1·00
July	12·0	32·9	0·93	8·0	27·0	1·13	—	—	—
Total	12·0	30·6	1·12	10·7	29·5	1·11	11·5	30·9	1·07
				1947					
April	13·7	31·5	1·22	14·2	32·3	1·18	—	—	—
May	8·9	28·9	1·02	12·5	31·1	1·13	—	—	—
June	14·0	32·5	1·13	13·2	31·3	1·19	—	—	—
Total	10·7	30·0	1·10	13·0	31·4	1·17	—	—	—

	Total 1946 lb.	1946 ins.	1946 K.	Total 1947 lb.	1947 ins.	1947 K.
April	11·5	30·5	1·12	14·0	32·1	1·18
May	11·0	29·7	1·11	11·6	30·6	1·13
June	10·6	30·8	1·08	13·3	31·5	1·18
July	10·0	30·0	1·03	—	—	—
Total	11·0	29·9	1·11	12·4	31·1	1·15

Large spring fish (3 winters).

Smolt age:	1 lb.	1 ins.	1 K.	2 lb.	2 ins.	2 K.	Total lb.	Total ins.	Total K.
				1946					
Feb./Mar. .	22·0	36·1	1·22	25·7	38·0	1·21	24·4	37·4	1·21
April	25·5	38·8	1·18	21·2	37·3	1·13	22·4	37·7	1·14
Total	22·6	36·5	1·21	24·4	37·8	1·19	23·9	37·4	1·20
				1947					
Feb./Mar. .	27·0	38·4	1·22	26·5	39·7	1·17	26·7	39·1	1·24
April	24·3	38·2	1·21	24·2	37·9	1·24	24·2	38·0	1·23
May	—	—	—	20·1	35·3	1·27	20·1	35·3	1·27
June	—	—	—	27·0	41·0	1·09	27·0	41·0	1·09
Total	23·9	38·3	1·21	23·6	37·6	1·23	23·7	37·8	1·22

Previous Spawners (with SM's).

Month	1946 lb.	1946 ins.	1946 K.	1947 lb.	1947 ins.	1947 K.
Feb./Mar. .	22·3	35·8	1·08	17·0	34·6	1·14
April	12·0	30·7	1·15	15·5	34·9	1·01
May	24·0	38·5	1·18	13·0	32·9	1·01
June	7·4	26·2	1·16	6·8	25·7	1·11
July	8·0	28·0	1·11	7·2	26·0	1·14
Total	13·2	30·4	1·12	9·3	28·3	1·14

(4) Large spring fish (3 winters)

	1946 Number examined = 31			1947 Number examined = 20		
	lb.	inches	Date of capture	lb.	inches	Date of capture
Minimum	18·75	34·8	18. March	15·5	34·8	15. April
	17·0	35·6	17. April	15·8	32·2	23. May
Mean	23·9	37·4	—	23·7	37·8	—
Maximum	34·0	42·5	18. March	33·3	42·4	15. April
	38·0	42·0	11. March	34·5	42·3	16. April

(5) Large summer fish (3+ winters).

One taken in each year:

1946, 26·0 lb., 39·0 inches, captured on 22. May, and
1947, 24·8 lb., 40·9 inches, captured on 15. April.

(6) Very large spring fish (4 winters).

One taken in each year:

1946, 30·0 lb., 41·5 inches, taken on 11. March, and
1947, 27·0 lb., 40·1 inches, taken on 10. March.

(7) Previous spawners (with SM's)

	1946 Number examined — 26			1947 Number examined — 35		
	lb.	inches	Date of capture	lb.	inches	Date of capture
Minimum	6·0	24·6	20. June	5·0	23·2	8. July
	6·25	24·4	—			
Mean	13·2	30·4	—	9·3	28·3	—
Maximum	28·0	41·7	7. May	22·0	36·9	8. April

Condition coefficients. The relationship between weight and length may be conveniently examined by means of the condition coefficient (see Went, 1938, for the method of calculation). In Table 14 the mean monthly condition coefficients have been given for the more important

Table 14. Average monthly condition coefficients (K.) in the more important age-groups.

Month	1946 Age-group (in winters)					1947 Age-group (in winters)			
	1+	2	2+	3	with SM's	1+	2	2+	with SM's
Feb./Mar. ..	—	1·06	—	1·21	1·08	—	1·12	—	1·14
April	—	1·10	1·12	1·14	1·15	—	1·22	1·18	1·01
May	1·13	1·13	1·11	—	1·18	1·12	1·13	1·13	1·01
June	1·16	—	1·08	—	1·16	1·19	1·11	1·18	1·11
July	1·13	0·88	1·03	—	1·11	1·17	—	—	1·14
Total	1·15	1·10	1·11	1·20	1·12	1·17	1·16	1·15	1·14
Spring fish .			1·11					1·17	
Summer fish			1·13					1·18	

age-groups. In 1946 the fish had on an average slightly lower condition coefficients than in 1947, and the spring fish of both years had slightly lower condition coefficients than the summer fish. The average condition coefficient for 1946 was the lowest yet recorded in these investigations into the life history of the Shannon salmon, the 1947 figures being somewhat an improvement on those of 1945, which were the lowest recorded in previous years (W e n t, 1943 and 1946).

Erosion. The limited number of small spring fish taken in June and July only showed erosion of the scales and the remainder were free from erosion.

3. Runs of fish.

The return of catches accurately represents the runs of fish into the freshwater portion of the river. In Table 15 the estimated monthly proportions of the total runs for each year from 1941 to 1947, inclusive, have been given. It will be seen that whilst there are marked fluctuations in the proportions of the runs of the different months in different years, the general form of the distribution is similar for each year. In order to study the actual runs of fish more closely, the numbers running in the three periods for each month (1st to 10th, 11th to 20th, and 21st to end of month) have been indicated in Table 16. These figures can be appreciated more readily in diagrammatic form (Figure 1).

In common with most summer rivers in Ireland the incoming populations in the Shannon in 1941 were superior to any year which has followed, the minimum being in 1945. The peak of the runs of the grilse in 1947 was very late, occurring in the first period of July, instead of in June, as in former years. This was, in fact, also experienced in other Irish rivers during 1947.

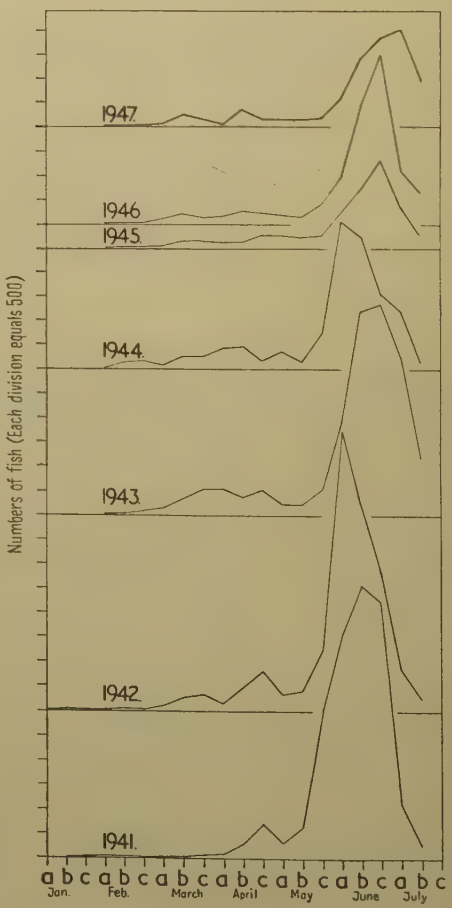


Figure 1. Showing the strengths of the runs of the incoming populations.

Table 15. Monthly percentage of total catch in the years 1941 to 1947 inclusive.

Month	1941	1942	1943	1944	1945	1946	1947
Feb./Mar.	1·0	4·9	6·3	7·7	8·3	5·0	6·1
April	5·0	8·1	7·9	8·8	8·1	6·7	6·8
May	18·2	10·8	5·3	11·2	11·2	7·1	5·9
June	69·4	70·0	56·6	61·5	55·3	64·8	45·7
July	6·4	6·2	23·9	10·8	17·1	16·4	35·5

Up to the 20th May the bulk of the fish were spring fish and thereafter the summer fish predominated. Therefore, if we take the runs of fish up to the 20th May, some indication of the fluctuations of the runs of spring fish can be obtained (Table 17). This table shows that in the case of the Shannon the early running fish increased in number somewhat from 1941 to 1942, thereafter dropped to 1945, showed a slight increase in 1946, and dropped again in 1947. Fluctuations in the summer fish may also be indicated from the returns. In Table 17 the summer fish (runs after 20. May) have been similarly treated.

Examining these two tables we can see that the good runs of summer fish in 1941 were followed in 1942 by improved runs of spring fish.

Table 16. Estimated runs of fish based on the returns of Thomond Weir.

Period	1941	1942	1943	1944	1945	1946	1947
1.—10. Jan. ..	0	22	—	—	—	—	—
11.—20. „ ..	8	39	—	—	—	—	—
21.—31. „ ..	18	10	—	—	—	—	—
1.—10. Feb. ..	40	11	3	6	4	20	11
11.—20. „ ..	40	52	13	127	—	20	17
21. Feb. to end of month ..	6	29	95	172	9	20	35
1.—10. Mar. .	18	108	151	86	58	111	70
11.—20. „ .	38	295	369	257	139	231	231
21.—31. „ .	15	332	527	265	168	142	142
1.—10. Apr. ..	79	165	551	420	103	194	62
11.—20. „ ..	300	495	389	452	107	275	354
21.—30. „ ..	711	804	516	192	293	252	159
1.—10. May ..	303	357	227	373	288	201	151
11.—20. „ ..	663	410	211	132	207	152	150
21.—31. „ .	3028	1220	544	731	278	403	190
1.—10. June..	4507	5725	1924	3056	728	998	566
11.—20. „ ..	5523	4249	4184	2747	1221	2463	1416
21.—30. „ ..	5229	2860	4322	1540	1834	3496	1849
1.—10. July ..	1142	891	3241	1190	894	1103	2023
11.—19. „ ..	275	246	1169	104	249	657	960
Total	22003	18325	18446	11940	6610	10738	8386

The reduction in the runs of summer fish in 1942 was not, however, followed by a comparable decrease in the runs of spring fish in the following year. The strength of the runs in the years from 1943 of spring and summer fish appear to follow one another closely. In other

Table 17. Runs of fish before 20. May (spring fish) and after (summer fish).

	1941	1942	1943	1944	1945	1946	1947
Spring fish							
Numbers of fish running up to 20. May	2299	3134	3052	2482	1376	1618	1382
Percentage of 1941 number	100	136	133	108	60	70	60
Summer fish							
Numbers of fish running after 20. May	19704	15191	15394	8458	5234	9120	7004
Percentage of 1941 number	100	77	78	48	27	46	36

words, a good run of grilse may or may not be followed by a good run of spring fish in the following year. On the data at our disposal it would not seem possible to anticipate even approximately the strength of the runs of spring fish from the known runs of summer fish in the year previous.

4. Fluctuations in the numbers of fish in the different age-groups.

The relative numbers of each age-group running in the five years 1941 and 1944—47, inclusive, may also be calculated (Table 18). These results are interesting because for the first time in any Irish river have we been able to show reasonably accurately the fluctuations in the numbers of the different age-groups (Figure 2). There were more marked fluctuations in the summer fish than in the spring fish. It has always been well recognized that fluctuations in the grilse in most rivers in Ireland are greater than in other age-groups. In consequence the yield in those rivers, relying for the most part on grilse, fluctuates to a greater extent, generally speaking, than in the spring salmon rivers. These extreme fluctuations in a grilse river are well illustrated by the Kerry Blackwater (W e n t, 1947) for which catch figures are available for a period from 1875 to 1945. Taking the average annual yield (number of fish) over that period in the Kerry Blackwater, the fluctuations have ranged from 267 % of average in 1894 to 8 % of average in 1929. It is doubtful whether any Irish spring fish river over a similar period has shown such marked fluctuations. The previous spawners, depending as they do in the ultimate on the runs of maiden fish a year earlier, show similar fluctuations to the grilse.

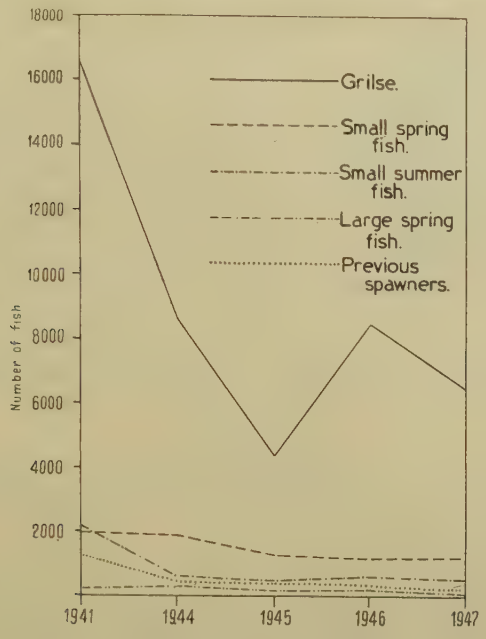


Figure 2. Fluctuations in the numbers of fish in the different age-groups.

5. General discussion of results.

A comparison of the results of the examination of material for the years 1946 and 1947 confirms that the River Shannon to-day must be regarded as a summer-salmon river. There is certainly no evidence from the present investigation and those conducted previously (W e n t, 1943 and 1946) that a transitional stage in development has been reached. The variations from year to year, from 1941 to 1947

Table 18. Actual numbers of fish running in the different age-groups in the years 1941, 1944—47 inclusive (to the nearest 10).

Age-groups (in winters)	1941	1944	1945	1946	1947
1+	16,500	8,860	4,350	8,500	6,470
2	1,980	1,860	1,280	1,150	1,150
2+	2,110	550	460	590	180
3	150	250	140	180	130
3+	—	10	—	+	10
4	20	—	—	+	30
with SM's	1,230	410	380	310	420
Total	22,000	11,940	6,610	10,740	8,390

+ Present but less than 5.

inclusive, are such as one might expect in a river which has not been subjected to the disturbing hand of man.

That it is now possible to make a reasonably accurate estimate of the numbers in the different age-groups in the Shannon is also important, as generally speaking there is no immediate prospect of obtaining such information from most rivers in Ireland or Great Britain. What is needed, however, is a series of further observations over, say, not less than ten years. When this information is available, a really useful discussion of the fluctuations might be undertaken. With this end in view the Fisheries Director of the Electricity Supply Board, Mr. Liam Forde, has undertaken to collect suitable material in future years.

The actual fluctuations which we have been able to estimate so far are, however, of great interest to fishery biologists.

7. Summary.

1. Material from salmon captured in the Shannon in 1946 and 1947 was examined, and mean size and condition coefficients in the various age-groups were calculated.

2. The bulk of the fish belonged to the two-year smolt class, the one-year smolts comprising 13·5 % and 16·5 %, being somewhat more numerous than in 1944 and 1945. The proportion of three-year smolts in 1946 (3·8 %) was considerably lower than that of 1947 (9·4 %) which did not, however, reach the high proportions of 1944 (12·9 %). The fish which showed on their scales marked freshwater growth in the spring prior to migration as smolts (type B smolts) were more numerous than those showing little or no such growth (type A smolts).

3. Grilse (fish which had spent just over a year feeding in the sea) were most important, forming more than three-quarters of the total catch by numbers. Small spring fish (fish which had spent two full years feeding in the sea) were again the second most important age-group.

4. Over 80 % of the fish had lengths less than 27·95 inches.

5. The average condition coefficient in 1946 was the lowest annual value recorded for the Shannon.

6. The strength of the runs of the incoming populations was discussed and is shown in Figure 1.

7. Fluctuations in the actual numbers of fish in the different age-groups in the year 1941 and 1944—47, inclusive, have been estimated (Table 18) and it was shown that those of the grilse were greater than those of the other groups of maiden fish.

8. Acknowledgements.

I wish to take this opportunity of again thanking Mr. Liam Forde, Shannon Fisheries, Limerick (Fisheries Director of the Electricity Supply Board) for collecting the material on which this investigation was based.

References.

Went, Arthur E. J., (1938). "Salmon of the River Shannon." Proc. R. Irish Acad. 44, B, 261—322.
Went, Arthur E. J., (1943). "Salmon of the River Shannon." Proc. R. Irish Acad. 49 B, 151—75.
Went, Arthur E. J., (1946). "Salmon of the River Shannon: 1944 and 1945." Jour. Anim. Ecol., 15, 155—169.
Went, Arthur E. J., (1947). "Salmon of the Kerry Blackwater". Sci. Proc. R. Dublin Soc. 24. (N. S.), 179—187.

The Eel Fisheries of the River Bann, Northern Ireland, and Observations on the Age of the Silver Eels.

By

Winifred E. Frost.

Freshwater Biological Association, Wray Castle, Ambleside, England.

I. Introduction.

The fisheries for silver eels (*Anguilla anguilla* L.) on the River Bann, Northern Ireland, are probably the largest of their kind in western Europe. In the autumn of 1943 I was privileged, through the courtesy of the late Major P. E. Shepherd, O.B.E., M. Inst. C.E., Director of Works for the Northern Ireland Government, Mr. W. J. M. Menzies, F.R.S.E., Freshwater Fisheries Advisor to Ministry of Finance, N. Ireland, and Captain W. E. Ellis, Managing Director of Toome Eel Fishery Ltd., to visit these fisheries to observe them in operation. During the visit, which lasted from 28th September to 6th October, much information about the elvers and the yellow and silver eels of the River Bann and Lough Neagh was gained; knowledge of the silver eels was extended by length measurements made in the autumn of 1944, 1945, and 1946 and by the examination, for age determination, of a sample of male fish in 1944. It was thought that some account of the eel fisheries and of the eels of Lough Neagh and the River Bann, based on the information obtained from the visit and the material examined subsequent to it, would be of interest, particularly in view of a large-scale experiment which is being carried out on the River Bann, namely, the capture of millions of elvers at the head of the tidal waters and their transference to the upper part of the River and into Lough Neagh (Menzies, 1936).

I wish to acknowledge with gratitude the help given to me by Major Shepherd, Mr. Menzies and Captain Ellis who during my visit explained and demonstrated the construction and working of

the eel weirs, arranged for my meeting the fishermen, and put at my disposal many facts and figures about the fisheries. Their help on technical matters during the writing of this account has been invaluable.

Lough Neagh is the largest lake in the British Isles, having an area of 153 square miles (Fig. 1). It receives, besides small streams, the Rivers Blackwater, Maine, Upper Bann, Ballinderry, and Moyola, and it is drained by the Lower Bann (hereafter referred to as the River Bann) which discharges into the sea at Castlerock. The total catchment area of Lough Neagh and the Lower Bann is 2,126 square miles, of which 1,900 square miles drain into Lough Neagh. Lough Neagh is 52 feet above sea level, it has a mean depth of 40 feet and a maximum depth of 102 feet (Murray, 1910). The lough lies on hard volcanic basalt and is surrounded by flat pasture land.

Figure 1.
Lough Neagh and the River Bann, Northern Ireland.

The River Bann between Lough Neagh and the sea is a wide river, 36 miles long, with a comparatively narrow outlet on the north coast of Ireland at Castlerock (Fig. 2). The geological nature of the river bed is the same as that of the lough. The width of the river averages about 240 feet. The variation in volume and velocity of the flow may be appreciated from the fact that the rate of discharge per minute may range from 20,000 to nearly 1,000,000 cubic feet. The river is navigable throughout its course except in five places where short navigation canals take the traffic. About two miles below Lough Neagh is a small lake, Lough Beg, about 2½ miles long and 1,400 acres in area. The river between Lough Neagh and the tidal reach (one mile above Coleraine) has been defined as the boundary between the counties Antrim and Derry, and the east and west banks of the river are therefore referred to as the Antrim and Derry side respectively.

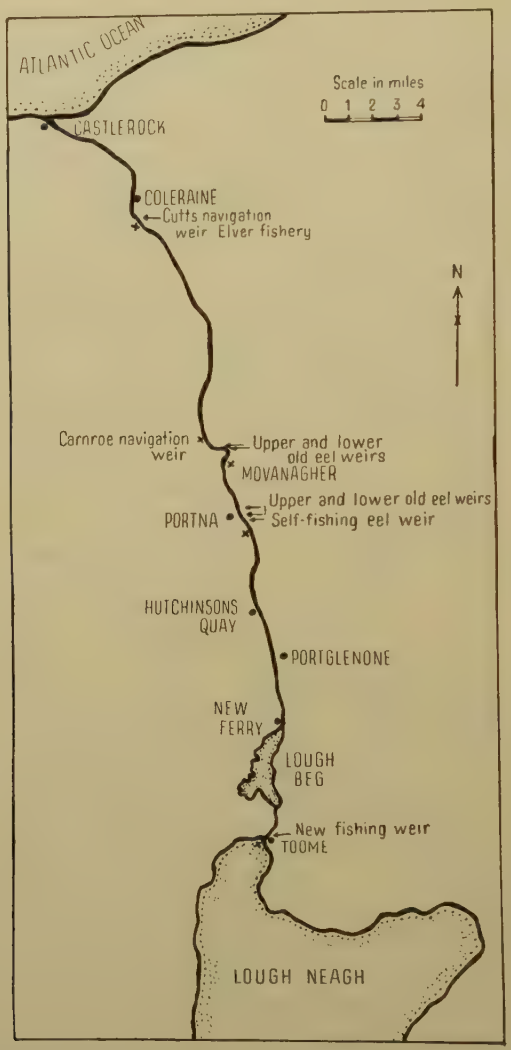


Figure 2. Lower River Bann showing location of eel weirs and elver fishery. Sluices or navigation weirs marked by a cross.

There are five navigation weirs or sluices on the Bann (Fig. 2). The lowest weir, about six feet high, is at Cutts, six miles from the mouth of the river at the top of the tideway. In 1937 this weir was replaced, on the Derry side, by sluices. Further upstream there is a weir at Carnroe and one at Movanagher. The weir at Portna was removed and replaced by sluices in 1940. Formerly at Toome there was a stone weir across the exit of the river from Lough Neagh. Today this structure remains near to both banks but the central portion has been replaced, between 1931—38, by a battery of five sluices which make it possible to control the discharge from the lough. These sluices were

erected and the River Bann downstream of them deepened and widened during the years 1930—41.

On Lough Neagh and the River Bann there are three types of fisheries for the eel (*Anguilla anguilla* L.) during its life in fresh water:

1. A commercial fishery for silver or migrating eels carried out by the Toome Eel Fishery Ltd., at their six eel weirs on the River Bann between Lough Neagh and Cutts weir (Fig. 2).

2. An illegal commercial fishery for yellow or feeding eels, which is carried out by local fishermen in Lough Neagh.

3. An experimental fishery for elvers at the lowest weir on the River Bann (Cutts) (Fig. 2). The elvers are used to stock the upper part of the river and Lough Neagh.

II. Fishery for Silver Eels.

Description of the Fisheries.

The eel which ascends the river from the sea as an elver spends some years as a yellow eel feeding and growing in fresh water. In due time this form changes into the silver eel, which is ready to migrate to the sea to breed. Silver eels migrate in large numbers so that there is at the time of migration a considerable concentration of eels passing down stream and the fishery is located and designed to intercept this concentration. The interception is effected by a system of barriers usually made of wood or stone set across the river and known as an eel weir. In the barriers are openings called *eyes* towards which the fish are directed so that they may be caught, usually in a net. Such a fishing weir may not legally extend across the whole width of the river, one tenth of which in the deepest part must be left free; this is the "free" or "King's gap".

The locations of the six weirs on the lower part of the River Bann proceeding up river towards Lough Neagh, are as follows (Fig. 2):—

Two weirs at Movanagher, about 12 miles above Cutts weir.

Three weirs at Portna, about 3 miles above Movanagher, consisting of

(a) Two weirs, the upper and lower old weirs, separated by about 50 yards.

(b) One self-fishing weir situated about 400 yards above (a).

One weir at Toome, the new fishing weir, situated about a quarter of a mile below the exit of the River Bann from Lough Neagh.

These weirs are of three different types; (1) the old type as seen in Portna upper and lower old weirs and in the two at Movanagher, (2) the modern type as seen in the new fishery at Toome, and (3) the modern type as seen in the self-fishing weir at Portna. I would like to record with gratitude how much the descriptions which follow owe to Major Shepherd who supplied most of the information on which they are based.

The old weirs.

The upper and lower weirs at Portna and the two at Movanagher are of the old type most commonly found elsewhere.[1]) The weir consists of a series of pairs of walls of wattle locally termed *skeaghs*[2]) each of which in the shape of a V with the apex pointing upstream, and between each pair of consecutive V's, at their downstream ends, is a gap or *eye* of about 10 feet into which a long conical *coghill* net

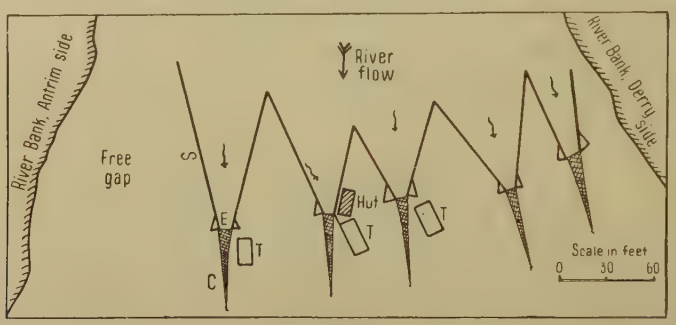


Figure 3. Plan of the old eel weir (upper) at Portna, wattle skeagh type.
S, Wattle skeagh. C, Coghill net.
E, Eye, gap between skeaghs. T, Storage tank for eels.

is set (Fig. 3, Plate I (a)). A *skeagh* is built of rectangular sections of frames of wattle, 30 feet long by 6 feet high, which are made by weaving together light and pliable saplings. The sections are then taken into the river, where they are slipped into position, on the upstream side, among larch poles which have been driven into the river bed. The wattle sections are secured to the poles and pushed down so that they rest in close contact with the bed of the river. Water passes through the interstices of the wattle but the eels are led to the eyes where the coghill net is fixed during fishing hours. This net is permanently attached to a three-sided frame consisting of a base pole and two side poles called *lurgs*[2]). The frame with its net is dropped into the eye, the base resting against a sill on the bed of the river, and the lurgs against a part of the weir, the breast-pole. The coghill net itself is a long tapered bag with a mouth between 4 and 6 feet deep and 6 feet wide. The net is about 14 yards long, of which 6 yards are in the body of the net and 8 in the tail. Since the weirs are located in rapids, the force of the water is sufficient to keep the net open

1) The pictorial map of Galway (1651) indicates that the eel weir ("Lesser Weir") on the River Corrib was similar in structure to these weirs. (Went 1944).

2) The names used for some parts of the weir are of etymological interest, and I am indebted to Miss Màire Walsh, of Dublin, for the following remarks:— "Skeagh" probably comes from the Irish word *Sciath* meaning a shield, which in olden days was made of wicker covered with leather; hence it could mean a wicker-work partition, a description which would suit the skeagh. *Lurg* is an Irish word meaning a club, staff, or log of wood, and *Raca* is Irish for a rake.

a)

b)

c1) c2)

Plate I. (a) Old eel weir (upper) at Portna, wattle skeagh type. (b) New fishing weir at Toome, looking downstream. (c1) Self-fishing weir at Portna, under construction. (c2) Self-fishing weir at Portna, looking downstream.

and stretched down river and also to prevent the return of the eels, so that there is no need for valves in the net. The mesh of the net is graded down its length from 2½ inches, knot to knot, in the upper part of the body to ¼ inch, knot to knot, in the tail. The end of the net is tied by a piece of cord to which a small peg is attached. The cord is wrapped round the end of the net and the peg pushed under the lapping. At sunset the fishermen set the nets and at intervals during the night they lift and empty them. The nets are reached by a long flat-bottomed boat, a *cot*, propelled by a pole, a skilled task against a strong river. The boat is brought alongside the net, the tail end of which is lifted out of the water by a huge crook, *raca*[2]). The end is then opened and the contents are shot into a tub, called a *cooler*, in the boat. The eels are later transferred from the tub and kept alive for market in large slatted wooden boxes, *tanks*, secured to the structure of the weir so that water flows through them. Built on to the structure of the weir are two wooden bunkhouses fitted with sleeping bunks and a fire-place for the accommodation of fishermen during their night's work. There is also a footbridge reaching across the river.

These old weirs have two main disadvantages; they obstruct the flow of the river, especially during floods, and their efficiency is reduced by flood conditions (page 367).

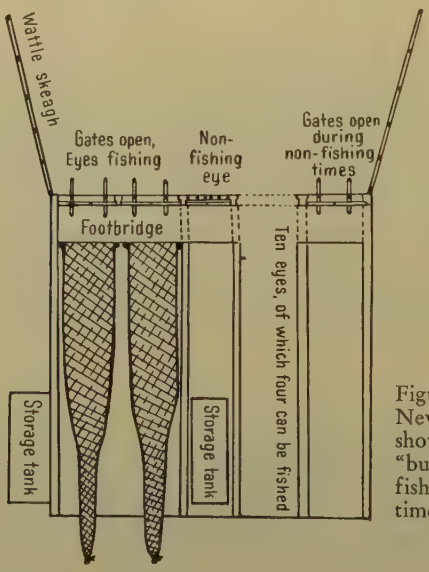


Figure 4.
New fishing weir, Toome, showing arrangement of "butterfly" gates during fishing and non-fishing times.

The new fishing weir at Toome.

Until 1932—33 there were two weirs of the skeagh type at Toome, one above the railway bridge and one below the road bridge, but when the Bann drainage scheme was undertaken both these weirs were removed as obstacles to flood discharge, and in 1933—34 a different

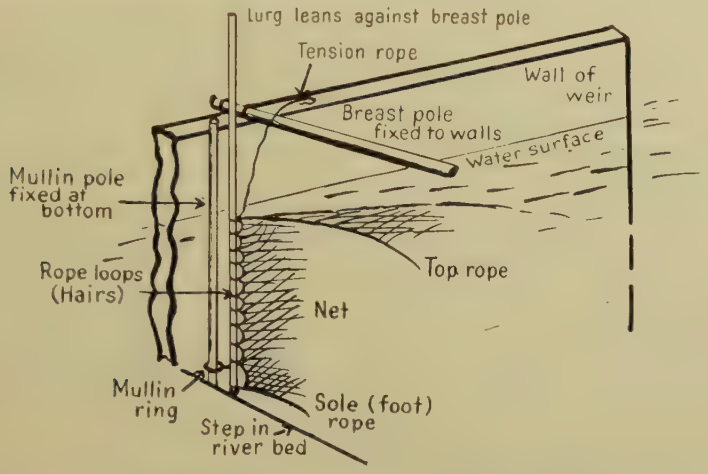


Figure 5. Diagrammatic sketch to show attachment of net at new fishing weir, Toome.

type of weir was constructed below the road bridge. Here the wattle skeaghs were replaced by "butterfly" gates made of timber and arranged to swing on a central pivot. When the weir was fishing the gates were closed, and the water and eels diverted through the eyes, in each of which a net was fixed. In 1945 this was demolished and the present weir, which operates on the same principle but has certain features not embodied in its predecessor, was constructed. This weir (Fig. 4, Plate 1 (b)) consists of an approach skeagh of wattle on each side of the river, arranged to leave a King's gap at one side, and a series of parallel reinforced-concrete walls through the gaps between which the water flows. All these gaps are fitted with "butterfly" gates constructed of metal-mesh screening instead of wood. Eight of the gaps, the fishing eyes, can be fitted with nets; the others in the centre of the weir cannot be so equipped. When the weir is working the central gates are closed but those in front of the fishing eyes are open. Thus the eels can pass with the water into the nets fixed in the eyes. If it is desired to omit fishing any net the "butterfly" gate in front of the eye is closed. When the river is low and the amount of water going through the eyes is insufficient to stretch the nets satisfactorily, a wooden shutter inserted behind a butterfly gate will block its eye and increase the flow of water through the remaining ones, insuring that the nets in those eyes which are fishing are stretched. During non-fishing time all the gates are open and there is free passage for water and fish throughout the length of the weir.

The nets are the traditional coghill as used at Portna old weirs. At Toome, however, the net is not fixed to a frame but when needed is mounted on two stout wooden poles *(lurgs)* in the following way (Fig. 5). The fisherman, standing on the weir, holds one of the lurgs and threads one side of the mouth of the net on to it by means of

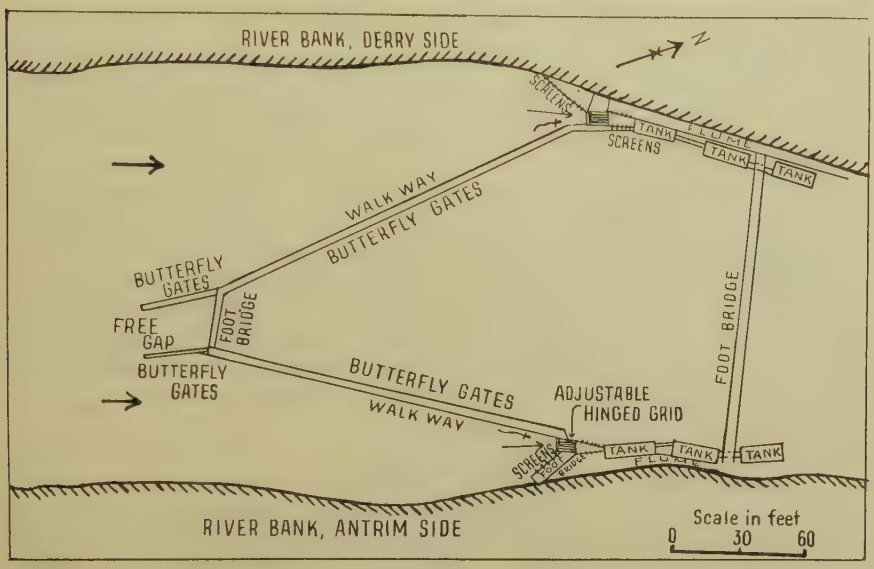
rope loops *(hairs)* and then similarly mounts the other lurg on the other side. After securing the bottom of the net by passing the sole rope through a staple in the lower end of each lurg, he shakes the rope loops down the lurgs and thus collapses the net. Attached to each lurg is an iron ring *(mullin ring)* and on each side of the fishing eye there is a stout iron pole *(mullin)* driven upright into the bed of the river.

The fisherman now raising the lurgs, slips the iron ring of each over a mullin, and drops the two lurgs simultaneously, vertically, to the river bottom, the rings sliding down the mullins, thus dropping the net in the eye. The mouth of the net is now opened by pulling the rope loops up the lurg by means of the tension rope which is attached to the head of the net. This setting of the net is essentially the same as that described by W e n t (1945) for the eel weirs of the River Erne, and several of the terms used which "appear peculiar to the Erne" occur on the River Bann, although they may not refer to the same gear on the two rivers.

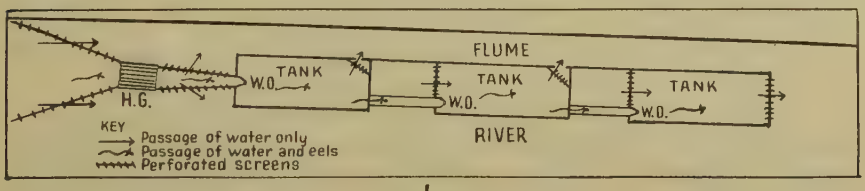
The net, at Toome, is 13 yards long in the body and 7 yards in the tail. At the entrance to the latter is a valve which is held open by two wooden loops, and attached to the junction of the body and the tail is a long fishing rope the end of which is tied to the weir. The mesh of the net is similar to that of the coghill used at Portna. The fishermen, who are accommodated in the two cabins built on the weir, can empty the nets when standing either on the structure of the weir or on the wooden eel tanks moored alongside, which resemble those at Portna. The tail end is hauled up by means of the fishing rope, opened and the contents poured into the eel tank.

T h e s e l f - f i s h i n g w e i r a t P o r t n a.

The third type of weir is at Portna, about 400 yards above the old wattle weirs. It was built in 1940 and like the new weir at Toome, was designed to reduced to a minimum the amount of obstruction caused by the presence of a barrier across the river and yet to retain a high degree of fishing efficiency. It was also built to be self-operating. The weir was designed by Major P. E. S h e p h e r d who has experimented with it considerably in both design and construction. The weir, illustrated in Figure 6 and Plate 1 (c), consists of two leaders, one from each bank, which extend upstream and converge towards the middle of the river where they are separated by the King's gap. The leaders are made of reinforced-concrete trestles connected by butterfly gates fitted with metal-mesh screens. When the weir is fishing, the butterfly gates are closed. The eels are guided by the barrier, formed by the leaders, towards the banks of the river near each of which is a set of three concrete tanks in which the eels are trapped and where they are stored. Trapping is effected by the non-return wire cage or orifice which is at the entrance to each tank. A hinged grid at the entrance to the row of tanks also prevents the escape of eels upstream. The eels pass from tanks 1 to 2 and 2 to 3 through a submerged pipe. Water



(a)



(b)

Figure 6. (a) Diagram of self-fishing weir at Portna.
(b) Detailed diagram of the trapping tanks shown in 6 (a).
H. G., hinged grid, W. O., wire non-return orifice.

from the river enters each tank through a grating and leaves through another grating into the flume. When few eels are running the lower tanks may be closed off and the upper one used alone. A tank which is to be emptied of eels may also be sealed off from the others.

Comments on the fishing weirs.

The extent of the obstruction to river flow of a weir is greatest from the wattle skeagh (Portna and Movanagher) because it is a barrier whether it is working or not. On the new weir at Toome and the self-fishing one at Portna this obstructive effect is eliminated by the use of "butterfly" gates which are opened and so allow free passage of water when the weir is not operating. The obstruction caused by the weir is increased by the debris which lodges on its upstream face. It is difficult to remove the debris in wattle weirs but on the weirs with "butterfly" gates these can be turned *in situ* and the debris washed away by the river.

In a heavy flood the wattle weir at Portna is overtopped and ceases to fish, although this can be prevented to some extent by regulation of sluices above the weir. If the river is low its velocity may be insufficient to stretch the nets at Toome weir, but it is possible to close some of the eyes and so secure a satisfactory flow through those which are fishing.

The nets used on the wattle weirs and at the new fishing one at Toome when clogged with debris cease to fish or they may tear; in the cleaning, the eels may escape. This trouble does not arise at the self-fishery of Portna, as nets form no part of its construction.

Mention has been made of the storage tanks for silver eels which form part of each weir. All tanks being in the river are well supplied with running water and the fish may be retained for as much as two months before marketing without deteriorating in any way.

The Catch.

The open season for fishing at the weirs begins on 1st June and lasts until 9th January, and fishing is allowed from sunset to sunrise throughout that period. The number of eels taken each season varies

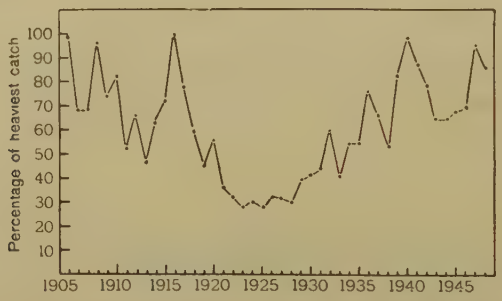


Figure 7.
The catch, as weight, of silver eels from all weirs for 1905 to 1948. Each annual figure is expressed as a percentage of the heaviest catch ever made.

and the catch fluctuates from day to day and from month to month. The fishermen think of the fishing season in terms of a series of "darks", that is, the monthly dark of the moon (page 370) and refer to the catch as so much for the September dark, October dark, and so on. Records of the annual, monthly, and daily catches have been kept by the Toome Eel Fishery Co. Ltd., some of which were kindly put at my disposal by Captain E l l i s. In appreciation of the confidential character of these data the actual figures are not given but are expressed on an arbitrary scale which does not affect their relative value.

Figure 7 shows that there is appreciable variation in the total annual catch from all six weirs and that the only significant trend which emerges is the decline in the catch from about 1921 to 1930. This might be explained by the fact that during the war years from 1915 to 1919, large numbers of yellow eels, many of small size, were

illegally taken out of Lough Neagh and that in consequence the potential silver eels of several later years were reduced in number. The rise in yield of silver eels from 1931 onwards gives some support to this explanation if it be assumed that Lough Neagh eels migrate after spending much the same time in fresh water as do Windermere eels (page 374), for then the better runs of 1931 and subsequent years would represent the protected and thus greater population of yellow eels of the post-war years.

The catch of eels from June to January shows considerable monthly fluctuations. The number of eels taken each month for ten years expressed as a percentage of the total fish caught during this time gives the following result:— June 0·4, July 1·5, August 9·9, September 32·4, October 45·2, November 8·6, December 0·4, January 1·6. The greatest number is caught in September and October, the latter being the month of maximum catch. The figure for January refers to one season only, when, after a dry autumn, 30 % of the season's catch was taken after heavy rains in January. Although the data for the individual years on which the percentages are based indicate that there may be appreciable variation in the catch for any individual month the percentages do give a sound index of monthly fluctuations.

The number of eels taken each night, even consecutive nights, can differ greatly and in some years the major part of the season's yield may be caught in a few nights (Fig. 8).

Factors affecting the Catch.

The catch is determined, to an appreciable extent, by the reactions of the silver eel to certain factors of its physical environment. The eel may respond to all or any of these factors and the response determines the character of the run and thus the catch at the weirs. "Run" is an elastic term and may refer to (1) the number of eels caught, e.g., a good or heavy run and a poor run, indicating respectively a large or small catch of fish, or (2) all those eels which migrate during any particular time interval, the limits of this being set by the responses of the silver eel to certain factors. Some of these factors as they appear to affect the Bann fisheries are considered below.

Water level.

It has long been known that a good run of eels coincides with a rise in water level, that frequently the run is best at the start of the rise, and that good catches of eels are associated with floods. The Bann fishermen find all this to be so. The relationship between catch and water level on the River Bann is shown in Figure 8 on which the nightly catch at Toome weir for 1942 is plotted against the height of the river recorded as the flow over Movanagher weir. It will be seen that an increase in catch usually coincides with a rise in water level. On the Bann the amount of water going down can be controlled to some extent by sluices and thus the catch of eels, in so far as it is affected by water level, may also be controlled.

Turbidity.

The Bann receives water from agricultural land and peat bogs, and when drainage from these discolours the water the fishermen find that fishing is better under such conditions than at the same water level without turbidity.

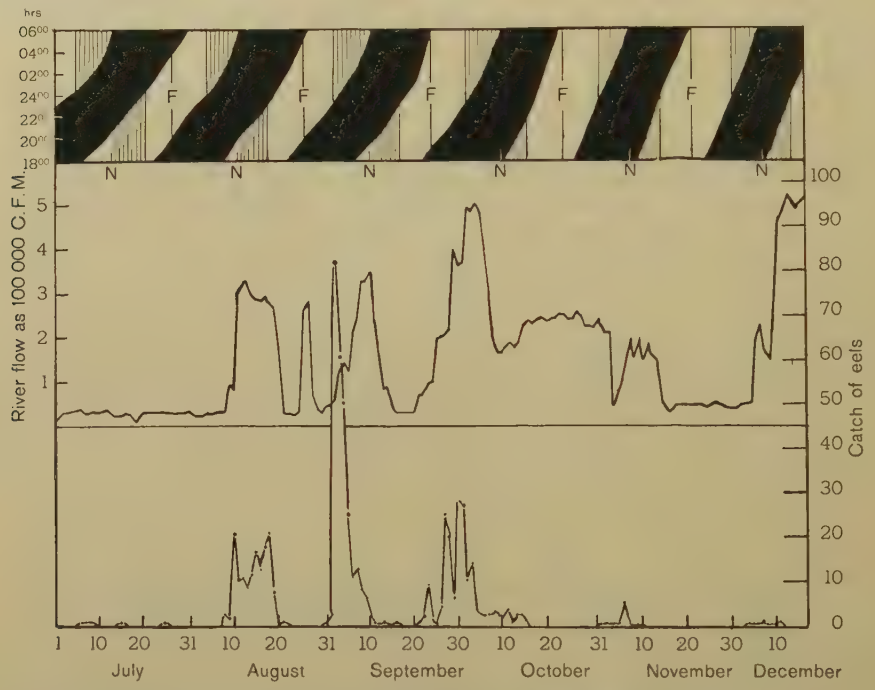


Figure 8. Nightly catch of silver eels at Toome in 1942 plotted in relation to river flow and phases of the moon and their nightly duration: moon shown as F. full, N. New, striations first and last quarters, and black, no moon.

Light.

It is well known that light tends to inhibit the migratory movements of eels. There is practically no downstream movement by day and the amount of moonlight affects the numbers migrating by night. On the River Bann, as elsewhere, the fishermen find that good catches are usually made during the "dark", that is, when there is little or no moonlight, and that poor fishing characterizes the full moon. The nightly catch for 1942 plotted in relation to the phases of the moon, these being indicated to show the nightly duration as well as the monthly periodicity of the moonlight, show that the best catches were made when some part of the night was dark (Fig. 8). The moon's light, although exerting a great influence on the run of eels, cannot always be isolated from other factors affecting the run. On the Bann, eels may run well even during moonlight if this coincides with stormy

weather and floods. When there is a moon and a low river the fishermen recognize both factors as contributing to the poor catch. A clear starlit night is regarded as unfavourable to a run of eels; such a night is often one of low temperature, in which case it is difficult to dissociate the effect of the two factors.

Wind.

The Bann fishermen assert that a strong southerly wind, that is, one blowing down Lough Neagh, makes for good fishing at Toome. They suggest that such a wind, disturbing the lough in the direction of the outflowing River Bann, stimulates the eels to move in that direction. It may be noted that a northerly wind, that is, one blowing down Windermere, is regarded as having the same effect on the eel fishing at the outlet of the English lake.

Temperature.

Temperature of the water at the fisheries is not recorded, and therefore correlation with this factor cannot be made. Fishermen have observed that eels do not run when there is frost, but since frosty weather often implies a starlit night, light in this case may be a contributory factor.

Physical obstructions.

These are presented by the sluices, one series of which is at the river's outflow from Lough Neagh, half a mile above the new fishery at Toome; the other is at Portna just above the fishing weirs there. These sluices, when down, may hold back the eels. This was suggested when it was observed on one occasion at Portna that a rapid rise in the number of eels entering the trap coincided with the raising of the sluices above the eel weir. It would seem possible to control the run by regulation of the sluices.

III. The Size and Age of Silver Eels.

Comments on the size of the silver eels of the River Bann are based on observations made during the visit and on some length measurements made then and subsequently. Remarks on the age of the fish are based on deductions from the length measurements and on results obtained from the examination of the otoliths of a sample of male eels.

The catch at the weirs includes both male and female eels. The sexes cannot be differentiated by any external characters but length may be used, with a high degree of certainty, to distinguish between male and female. Silver eels of less than 45 cm. long are, almost without exception, male, while longer individuals are female (Frost, 1945). This length criterion, which has been supported by internal examination of numbers of small silver eels from the River Bann, will be used here.

Length and Weight of Silver Eels.

Although a general idea of the size of the eels making up the catch was gained from observation, some attempt has been made to obtain a better index of the length distribution of a normal catch by taking length measurements of unselected samples of eels from several runs. The eels were measured alive, and the length was taken from snout to the tip of the tail. The samples were as follows:—

At Toome

6. Oct. 1943 144 eels, a random sample taken from the net.
6. Oct. 1943 208 eels, a random sample taken from storage tank.
Oct. 1943 132 eels, a whole night's catch.

Total 484

At Portna

Aug. to Oct. 1944	377 eels	A random monthly sample taken throughout each fishing season of 1944, '45, and '46.
Aug. to Nov. 1945	549 eels	
July to Nov. 1946	473 eels	

Total 1399

Thus the total number of eels measured is 1883; of these 484 were caught at Toome in 1943 and measured, by me, to the half inch below, and a total of 1399 was caught at Portna in 1944, 1945, and 1946 and measured, by the fish watcher, to the nearest centimetre. In Figure 9 these measurements are shown as length-frequency distributions. The data from Portna have been arranged in 3 cm. length-groups in order to eliminate "dog toothing"[1]) which characterized the graph when the original centimetre measurements were plotted. The data from Toome are given, as originally collected, in inches but they can be related to centimetres by the base line of the graph which is in centimetres. To afford a comparison and to throw light on the age of the Bann fish (page 374) the length-frequency distribution of 1,222 silver eels taken at the Freshwater Biological Association's experimental trap on the Cunsey Beck, a stream draining part of the Windermere catchment area, is also shown in Figure 9. These eels were measured in 1 cm. length-groups, but in order to facilitate comparison with the size distribution of the Bann fish, they have been plotted here in 3 cm. groups.

The range in length of silver eels, both male and female, of the River Bann is apparent from Figure 9; for both sexes the range is almost identical with that of Windermere fish. The most common length at migration for male eels of the Bann, as deduced from Figure 9, namely, 34·5 to 42 cm., coincides roughly with that for the Windermere male fish, and as judged from the same figure the modal length for female eels of the Bann, 49·0 to 58·5 cm., shows some coincidence with that for the female eels of Windermere.

[1]) It is difficult to explain this phenomenon. It has been suggested that the difficulty of measuring live eels may have given play to an unconscious bias for certain numbers or that because the tank from which the eels were taken held only one night's catch, the eels of any particular night may all have been of much the same size.

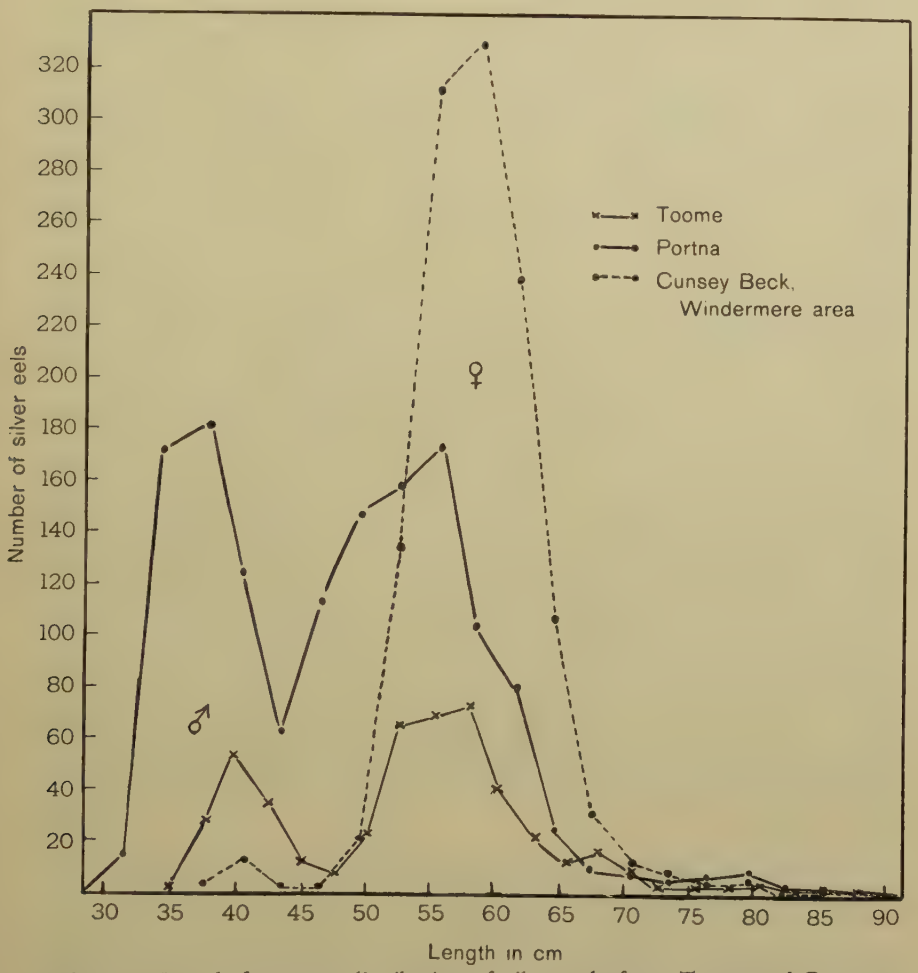


Figure 9. Length frequency distribution of silver eels from Toome and Portna on River Bann and from Cunsey Beck in Windermere catchment area.

The mean length of the male eels from Portna, that is, of the 553 individuals of 44·0 cm. or less in length, is 37·4 cm., and of the 846 females is 54·2 cm. Of the 484 Toome fish, 131, which were 45 cm. and less in length and therefore accepted as males, had a mean length of 38·6 cm.; the average length of the 353 females was 56·5 cm. Windermere eels are somewhat longer than those of the Bann because the males have an average length of 40·6 cm. and the females 58·2 cm.

During the visit no samples of eels were weighed and the following information is based on the remarks of the fishermen. The eels taken at the weirs range from 75 to 2270 g.; this includes the male fish which have a range of 75 to 170 g. Excluding these small males, the weight

of the majority of the eels captured is of the order of 510 to 570 g.; these would be female fish. Heavy fish, that is, individuals weighing 1370 g. or more, are not numerous and they are taken throughout the season. Female silver eels from Windermere catchment area have a range in weight similar to those of the Bann and an observed mean weight of 556 g.; the males weigh from 65 to 150 g. and have a mean weight of 113 g. Thus the range in, and mean, weight of both male and female silver eels of the Irish and English eels is of much the same order.

In Figure 9 the proportion of male to female eels among the Bann fish is high; of 484 eels measured at Toome 27·2 % are male (i.e., less than 45 cm. long) and of the 1399 from Portna 39·6 % were male. Although these figures should be accepted with some reservation, because the ratio of the sexes can only be known definitely from the examination of many random samples of fish and it is also possible that some males escaped through the net, the likelihood that they are an index of a reality is supported by the observations of the fishermen on the weirs. These men, who recognize two kinds of eels, "small" ones (males) and "others" (larger and therefore females), have noticed that the small fish, the number of which was low in the catch of previous seasons, have, since 1943, formed a relatively high proportion of the eels caught. Usually male silver eels are much outnumbered by females; for example, of the record catch of 680 eels at the Cunsey trap in 1943, only 3 % were male, and at the commercial trap in the Windermere catchment area the fisherman states that "smalls" always form an insignificant proportion of the catch of eels. At the Bann fisheries the recently observed high proportion of males is unprecedented and has aroused much interest; the matter is given further consideration later (page 380).

Age of Silver Eels.

Age determinations of silver eels of the River Bann are limited to the results obtained from a sample of male silver eels (page 375), but some indication of the age-for-length relationship of the female migrants may be obtained by inference from the information available about this relationship for Windermere eels; this will be considered first. Statements on the age of the eel refer to the time spent in fresh water and not to the total life, because the three years spent in the sea before its entrance into fresh water are ignored.

Age of females.

The female eels leaving Windermere catchment area range from 47 to 95 cm. in length and these fish have spent from 9 to 19 years in fresh water. It has been found (Frost, 1945) that the most common length of these migrants is from 54 to 60 cm. (a fact apparent from Figure 9) and that such fish have spent from 10 to 12 years in fresh water. The most common length of the Bann female silver eels, as

Table . Length distribution of a sample of 159 male silver eels.

Length in cm.	33·5	34·5	35·5	36·5	37·5	38·5
Number	2	4	8	12	30	29
Per cent. composition	1·26	2·51	5·05	7·58	18·90	18·20
Length in cm.	39·5	40·5	41·5	42·5	43·5	44·5
Number	33	19	9	7	4	2
Per cent. composition	20·80	12·00	5·53	4·40	2·51	1·26

deduced from Figure 9, is about 49·0 to 58·5 cm., a range which does not differ greatly from that of the Windermere fish. If now it be assumed that the length-for-age relationship established for the Windermere eels may be applied to the Bann fish, then in view of the approximate coincidence of the modal lengths it may be postulated that the age at which the majority of the Bann females migrate will be comparable with that for Windermere, namely, after 10 to 12 years in fresh water.

Age of males.

It has been mentioned that the fishermen have noted that there have been large numbers of small silver eels (males) in the catch of the weirs during recent years. In view of the possibility of a connexion between this phenomenon and the transport of elvers (page 378), interest in the age of these fish was aroused. Shortly after my visit I examined 20 male silver eels for age and the results suggested further investigation. Therefore in October 1944 I received, for examination, a box containing 166 small silver eels from the nets at Toome.

The eels were measured from the snout to the tip of the caudal fin to the 0·5 cm. below, weighed individually, and the sex determined by internal examination. Of the 166 fish, 159 were male and 7 were

Table 2. Age-for-length relationship of male silver eels. Number of fish in each age-group for each length-group and mean age for each length-group.

Centimetre length-groups	Number of fish in each age-group					Number of fish in each length-group	Mean age (years in fresh water) for each length-group
	VI	VII	VIII	IX	X		
34	2	1	—	—	—	3	6·3
35	1	—	—	1	—	2	7·5
36	4	3	—	—	—	7	6·4
37	3	6	2	—	—	11	6·9
38	6	8	6	1	—	21	7·1
39	2	7	6	1	—	16	7·4
40	7	5	4	—	1	17	7·0
41	1	1	1	3	1	7	8·3
42	—	1	—	1	—	2	8·0
43	—	—	2	4	—	6	8·7
44	—	—	—	1	—	1	9·0
					All fish	93	7·3

Table 3. Length-for-age of male silver eels, showing the mean length and its standard deviation for each age-group.

Age-group	Mean length (cm.)	Range (cm.)	Standard deviation
VI	37·9	34·5—40·5	1·76
VII	38·3	33·5—42·0	3·0
VIII	39·1	36·5—43·0	3·4
IX	41·0	34·5—44·0	5·23
X	40·4	39·5—41·0	2·12
All fish ..	38·7	33·5—44·0	4·18

Table 4. Weight-for-age of male silver eels showing the mean weight and range in weight for each age-group.

Mean weight (g.)	Range (g.)	Number of specimens
94·8	65—115	26
98·8	60—125	32
105·0	90—125	21
117·7	80—150	12
115	105—125	2
101·9	60—150	93

female. The data for six of these seven females are as follows:—44·5 cm. 150 gr., 46 cm. 180 gr., 46·5 cm. 205 gr., 51 cm. 195 gr., 52·5 cm. 250 gr.; one specimen was mislaid and no data are available.

The mean length of the 159 males was 38·5 cm., the range 33·5 to 44·0 cm. and the most common length 37·5 to 39·5 cm., and the mean weight was 103 gr. (Tables 1 to 4). Otoliths were used for age determination because they are the most reliable structures for this purpose; they were prepared for reading in the manner already described (F r o s t, 1945). Otoliths from 101 of the 159 males were examined and of these 93 were readable; on them the results given below are based. The data from the age determinations are presented in two ways, (1) as an age-for-length relationship so that the mean age of a fish at a chosen length is given, (2) as a length-for-age relationship so that the mean length attained by each year-class is given. The former gives the more useful information because it enables the age to be obtained when only the length is known; it also is a more reliable expression of the results as it recognizes that the age determinations are estimates, the length data, certainties. Both expressions are given here, however, to facilitate comparison with other work on the age of eels (F r o s t, 1945); the age-for-length data are given in Table 2 and those for length-for-age in Table 3.

It may be concluded from consideration of the two tables together that the majority of the eels migrate in their 7th, 8th, and 9th years, that is, after spending 6+, 7+, or 8+ years in fresh water, at which time they are 36·5 to 40·5 cm. long. There is an appreciable range in the age of the migrants (6 to 10 years) but only a fair range, 33·5 to 44 cm., in their length at migration. The mean age at migration is after 7·3 years in fresh water and the mean length 38·7 cm.

The mean weight for each age-group is given in Table 4, from which it will be seen that there is but little increase in weight with years and that the mean weight for all the fish examined is low.

Thus the male silver eel is younger and smaller than the female

(accepting the inferred age of the latter). This phenomenon characterizes silver eels which have been investigated from other European waters; for example, in Windermere the mean length of the male migrant is 40·0 cm. and weight 112 gr. and the average time spent in fresh water is 9 years, whereas the female has an average length of 60·0 cm. and computed weight of 410 gr. and leaves fresh water after an average of 12·3 years (F r o s t, 1945).

The age of the male eels of the Bann having been ascertained, the possibility of there being some association between the high proportion of males noted since 1943 and the transport of elvers (page 378) will be discussed (page 380).

IV. The Fishery for Yellow Eels.

The yellow eel is the phase when the fish is feeding and growing, and although at this time it is not in the perfect condition of the silver eel, it is an edible and marketable fish. There is an illegal fishery for such eels in Lough Neagh from March to October when eels are taken in draft nets and on long lines. Before the 1914—18 war draft netting was the main method of fishing, although legal action against it was taken in 1908—11 because the drafters fished Toome Bay during the autumn in order to include silver eels, then congregated there, in their catch. The great demand for yellow eels during 1914—18 encouraged draft netting; it was, however, less extensively practiced than formerly because the live-baited long line was beginning to replace it. This latter method has become increasingly popular and although today the draft net is employed in Lough Neagh, the steady fishery for yellow eels is by the long line.

The long line, which may be as much as 4 miles in length, is baited with fish, preferably small live perch, but failing this pieces of pollan (*Coregonus*), pollan plugs, are used. The use of pollan as bait, a practice of the war years with a resultant decline in the pollan fishery, has been virtually dropped. The line is usually set at night and lifted next day. It is stated that when set during the day the baits are more frequently taken by perch.

Long lining is wasteful as eels are caught without regard for the size of the fish, and the hooking of appreciable numbers of small individuals, which are retained by the fisherman, means a loss to both yellow and silver eel fisheries. Legal action to prevent the retention of these small eels has been taken, but the ruling that it is illegal to have in possession any 14 eels weighing less than 7 lb. allows of some latitude in interpretation which limits its effectiveness.

Information about the numbers or the length and weight of the eels taken by the fishery is not available. I saw a large catch of confiscated eels from which it seemed that the range in length and weight of the fish is considerable; some of them looked to be about 45 cm. long and 170 g. in weight, and others were 90 to 100 cm. in length and perhaps weighed 1820 g. The majority appeared to be about 65 cm. long and from 340 to 450 g. in weight. No eels were examined for age determination or measured for length distribution.

V. The Fishery for Elvers.

The yield of the yellow and silver eel fisheries of Lough Neagh and the River Bann is finally dependent on the number of elvers reaching the Bann catchment area which in turn depends on the annual run of elvers into the river. Because it has long been known that the navigation weirs on the river presented serious obstacles to the upstream migrations of these elvers their ascent has always been assisted by passes, channels cut in the weir close to the river bank and lined with a straw rope. When the drainage work began on the River Bann in 1930 it was realized that the progress of the elvers would be further obstructed by constructional works in the middle reaches of that river. In 1932 it was decided to trap the Bann elvers in the lower part of the river and then release them above any constructional obstacles; thus the "fishery" for them was established.

This "fishery" is not a commercial undertaking but a biological experiment and one carried out on a large scale. Detailed accounts of the number of elvers trapped throughout the season, of the number transported, and when transplanted have been kept since 1932. Such records are of great value and interest to workers on eels and through the kindness of Mr. M e n z i e s and Major S h e p h e r d they were put at the disposal of the Freshwater Biological Association. A detailed analysis of these data in which the catch of elvers has been related to various chemical, physical, and biological factors has been made by my colleague Miss R. H. L o w e, and it is hoped that this will shortly be published. In view of this and of the full account of the structure and working of the fishery given by Mr. M e n z i e s (1936), only an outline of the fishery for them will be given here, sufficient information for discussion of the possibility of a relationship between the transference of the elvers and the high proportion of males noted in the present day catches of silver eels (page 380).

The first obstacle to the ascent of elvers in the River Bann is the weir at Cutts near Coleraine, a place six miles from the mouth of the river and at the head of the tideway (Figs. 1 and 2). This weir, which is never topped by the tide, was chosen as the site for the elver fishery. The ascending elvers negotiate Cutts weir as they do the others on the River Bann, by elver passes at each bank of the river. At Cutts it was arranged that the pass should lead the ascended elvers, not to the open river, but into a trap. Details of the construction of pass and trap are given by M e n z i e s (1936). The first attempt to trap the elvers began with the run in 1932 but in this year the trapping arrangements were primitive and very few fish were caught. In 1933, 1934, and 1935 the arrangements, although improved and effective, were still in the experimental stage and therefore subject to alteration, but by 1936 the final form of the trap was achieved and its efficiency apparent.

The traps at Cutts, because of their position and construction, present a most satisfactory method of capturing the elvers of the Bann and it has been suggested that practically all the elvers entering the

Bann are trapped. Some, however, (what proportion of the run has not yet been established) do avoid capture as is evident from their having been seen at Carnroe and Portna weirs.

The catch of the elver fishery has been recorded since 1932, in which year they were noted as a total figure for the season, but in subsequent years details of the numbers taken in each run were also recorded and from 1938 daily records have also been kept. The total number of elvers taken each season, calculated on a basis of 1400 specimens to the pound, is given in Figure 10. It is only from 1936 onwards when trapping became stabilized that comparison between the catch of the

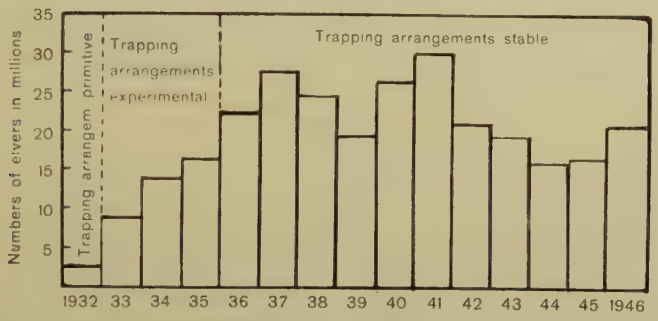


Figure 10. Estimated total number of elvers trapped each year at Cutts weir.

different years is justifiable. The great range in the catch of the years will be noticed. The numbers taken appear to bear no relation to the length of the season, which may extend from 6th March to 7th July, although generally it lasts from the first or second week in April until the middle of June. Figures for the catch taken in each month of the season from 1939 to 1943 show that usually May is the month when elvers are taken in greatest numbers, with April next in importance; June has considerably poorer catches.

The elvers ascend the Bann in "runs"; a run Miss L o w e describes as all those elvers which come up in a continuous stream during any period of time, and such a period may range in length from two days to the whole season. The elvers come up with the tide, which extends to Cutts weir. The elvers keep near the river bank but during slack water they can be seen in the centre of the river although they swim towards the bank as soon as the tide makes itself felt.

There are many factors, physical and biological, such as tides, temperature, light, etc. which influence the character of the run and the movements and the habits of the elvers, but as these matters have been dealt with by M e n z i e s (1936) and L o w e (unpublished report) they will not be considered here.

The trapped elvers are not stored but removed daily from the trap, two or three times in a day during a heavy run, and taken to destinations further up the River Bann, where, above any temporary constructional obstacles, they are turned into the river and lough. The

fish are dipped out of the trap into a net, and put into wooden boxes. Each box contains nine linen-bottomed trays; each tray is $15\frac{1}{2}'' \times 36'' \times 2''$, weighs 3 lb., and will hold approximately 8 lb. of elvers, that is, roughly 10,000 fish. The linen of the trays is damped, eight are filled with elvers, and the top tray is left empty; no water is added. When packed, the boxes are taken immediately, by motor transport, to four transportation points, three on the River Bann, viz., Hutchinson Quay, Portglenone, and New Ferry, and one on Lough Neagh near Toome (Fig. 2). These are approximately 18, 26, 30, and 36 miles, respectively, above Cutts weir. The number of elvers taken to each place varies from time to time but the daily records indicate that the greater part of the catch, distributed in approximately equal proportions, is transported to Hutchinson Quay, Portglenone, and Lough Neagh, whereas New Ferry is not so abundantly, nor so frequently, supplied.

VI. Discussion.

This discussion is concerned with the effects that the annual transference of the elvers from the tideway to places many miles upstream may have had on the fishery for silver eels on the River Bann.

It is well known that at silver eel fisheries the proportion of male to female eels is low. It has been noted, however, by the fishermen on the Bann weirs that a high proportion of males to females has characterized the catches since 1943 (page 374) and also that in 1948 the proportion was not so high as in previous years. The possibility that these phenomena may be associated with the transference of elvers from 1933 and particularly since 1936, receives support from the age of the silvers eels. It is known from the age determinations of the sample of 93 male silvers that these fish migrate after spending 6 to 10 years in fresh water (Tables 2 and 3). It may be concluded that male migrants derived from transported elvers would therefore first appear in 1939 and that the numbers of such males would increase as with each year a new year-class entered the migrant population, until by 1943 all the migrant age-groups would be represented (Table 5). It is inferred, from results obtained from Windermere, that in the R. Bann most female eels migrate after spending 10 to 12 years in fresh water but many may spend 14, 15, or even more years before migrating (page 375). It may be concluded that the females derived from transported elvers would migrate therefore at least four years later than the males, the first females migrating in 1943. Each subsequent year as another transported year-class would be added to the migrant eel population the number of females derived from transported elvers would increase and by 1948, 1949, etc. their numbers would have become considerable. Thus the age determinations (direct or inferred) show that the silver eels of the last few years, that is those eels which have exhibited the change in the proportion of the sexes noted above, are likely to have been descendants of transported elvers (although it will be some years before all the females of such descent are present),

Table 5. Relationship between the transported elvers and the silver eels derived from them. The age-groups of eels derived from each annual transportation of elvers (E) and the year of their migration as silver eels (in italic) is shown. Male silvers appear first in 1939 and females in 1943.

Year of elver transportation and of silver eel fishery	Sex	Age-groups of male and female eels, silver eels in italic							
		1933	1934	1935	1936	1937	1938	1939	1940
1933	♂♀	E							
1934	♂♀	I	E						
1935	♂♀	II	I	E					
1936	♂♀	III	II	I	E				
1937	♂♀	IV	III	II	I	E			
1938	♂♀	V	IV	III	II	I	E		
1939	♂	*VI*	V	IV	III	II	I	E	
	♀	VI							
1940	♂	*VII*	*VI*	V	IV	III	II	I	–
	♀	VII	VI						E
1941	♂	*VIII*	*VII*	*VI*	V	IV	III	II	–
	♀	VIII	VII	VI					I
1942	♂	*IX*	*VIII*	*VII*	*VI*	V	IV	III	–
	♀	IX	VIII	VII	VI				II
1943	♂♀	*X*	*IX*	*VIII*	*VII*	*VI*	V	IV	–
			IX	VIII	VII	VI			III
1944	♂	–	*X*	*IX*	*VIII*	*VII*	*VI*	V	–
	♀	*XI*		IX	VIII	VII	VI		IV
1945	♂	–	–	*X*	*IX*	*VIII*	*VII*	*VI*	–
	♀	*XII*	*XI*		IX	VIII	VII	VI	V
1946	♀	*XIII*	*XII*	*XI*	*X*	IX	VIII	VII	VI
1947	♀	*XIV*	*XIII*	*XII*	*XI*	*X*	IX	VIII	VII
1948	♀	*XV*	*XIV*	*XIII*	*XII*	*XI*	*X*	IX	VIII

and favour the suggestion that the transference of the elvers has been the cause of the change in sex ratio.

It will be interesting to see whether the change in sex ratio is a temporary or permanent phenomenon. If it is *temporary*, then the transportation of elvers has merely increased the total number of eels, of both sexes, in Lough Neagh, and the disturbance of the sex ratio is due to that difference in the age at migration of males and females to which

reference has just been made. It has been noted by the fishermen that the proportion of males, which was high from 1943 to 1947, was lower in 1948. One year's evidence, however, has little significance.

The increase in total population of eels will mean an increase in the weight of the total catch of silver eels. Such an increase will be slight at first, because males are smaller fish, but will become progressively greater as time goes on and the females also migrate, finally becoming stabilized at a higher level than formerly, when the original sex ratio is again established. The records (Fig. 7) indicate that something like this is happening but it will be impossible to say, at least for several years, if the total catch has increased permanently.

If the male silver eels continue to form a high proportion of the catch and the catch shows only a temporary increase and later a fall in weight, then it may be assumed that the ratio of the sexes has been *permanently* disturbed by the transportation of elvers. Two suggestions, both speculative, may explain how this has come about:— (1) If by transportation of the elvers Lough Neagh has become overstocked then the feeding for the eels is reduced and it appears possible that poor feeding is conducive to the production of males.[1]) (2) There is a hypothesis that the sex of eels is determined at fertilization and that male and female elvers tend to orientate to brackish and fresh waters respectively.[1]) It is suggested that in trapping the elvers some of these estuarine dwellers and therefore males have been transported to the fresh waters of Lough Neagh etc., and so added to the number of male eels normally there.

It will be some years yet before it can be known whether the change in sex ratio is temporary or permanent.

VII. Summary.

There are two commercial fisheries for eels (*Anguilla anguilla* L.) on the River Bann, Northern Ireland, a small fishery for yellow eels in Lough Neagh and a large fishery for silver eels at six weirs on the River Bann. These weirs are of three types, all described. There is a unique, non-commercial experimental fishery for elvers at the head of the tideway, six miles from the mouth of the river.

The catch of silver eels varied with the years, with the months, and with the night. The greatest number is usually taken in September and October and it appears that the best catches occur on nights when there is a rise in water level and during the dark of the moon.

The observed mean length of the male silver eels is 38·5 cm. (range 33·5 to 44·0 cm.), the mean weight is 103 g. (range 60 to 150 g.). The observed mean length of the female silvers is 55·0 cm. and the range 44·5 to 86·0 cm.; in weight the range is 150 to 2270 g. with most of fish weighing between 510 to 570 g.

It has been found from the examination of otoliths that the majority

[1]) References to the work and workers on these two points are given and discussed by Bertin, 1942.

of the male eels migrate after spending 6+, 7+, or 8+ years in fresh water when they are 36·5 to 40·5 cm. long. It appears that the most common length of migrating females is about 49·0 to 58·5 cm. and it is inferred that such eels have spent 10 to 12 years in fresh water.

The fishery for yellow eels in Lough Neagh is briefly described. The elvers entering the River Bann are trapped at the head of the tideway and transported many miles upstream where they are turned into the river and Lough Neagh. This fishery has been effectively carried out since 1936.

It is suggested that this transportation has been the cause of the high proportion of male to female silver eels which has characterized the catches since 1943. Three speculative explanations for this change in sex ratio are offered:— (1) that the transportation of elvers has merely increased the population of eels; the change in sex ratio would then be a temporary phenomenon, (2) that transportation has resulted in over-stocking, so that the eels are underfed, a condition which apparently tends to produce males, (3) that male elvers, which because of their sex would normally tend to live in the estuary, are now transported into fresh water. If either (2) or (3) is correct the change in sex ratio would be a permanent phenomenon. Some years must elapse before it can be known whether the change in sex ratio is temporary or permanent.

VIII. Acknowledgements.

The help of Major P. E. Shepherd, Mr. W. J. M. Menzies, and Captain W. E. Ellis has been gratefully acknowledged. I am deeply indebted to the late Major Shepherd, Director of Works, and to the Government of Northern Ireland for the loan of and permission to reproduce the plans and diagrams as shown in Figures 3, 4, 5, and 6, and the photographs on Plate 1, and also for the data in Figure 10. I thank Captain Ellis for supplying the data on which Figures 7 and 8 are based. I am greatly indebted to Mr. H. C. Gilson, Director of the Freshwater Biological Association, for his critical review of the manuscript and to my colleagues Mr. E. D. Le Cren and Miss R. H. Lowe for much helpful criticism and advice.

IX. References.

Bertin, L. 1942. "Les Anguilles." Paris.

Frost, W. E. 1945. "The age and growth of eels (*Anguilla anguilla*) from the Windermere catchment area." J. Anim. Ecol. **14**: 26—36, 106—124.

Menzies, W. J. M. 1936. "The run of elvers in the River Bann, Northern Ireland." J. Cons. Int. Expl. Mer, **11**: 249—59.

Murray, J. 1910. "Characteristics of lakes in general and their distribution over the surface of the globe. Report on the scientific results of the bathymetrical survey of the Scottish freshwater lochs." Challenger Office, Edinburgh.

Went, A. E. J. 1944. "The Galway Fishery." Proc. R. Irish Acad. **49**: C 5: 187—219.

Went, A. E. J. 1945. "Fishing weirs of the River Erne." J. R. Soc. Ant. Ireland. **75**: 213—23.

Editorial Note.

Dr. Edward H. Smith, who is retiring from the U. S. Coast Guard, has been appointed to the directorship of the Woods Hole Oceanographic Institution for a period of six years, from 1. July 1950. Columbus O'D. Iselin, Director since 1940, resigns his post on that date, to become Senior Oceanographer at the Institution.

Reviews.

N. W. Rakestraw. "The Conception of Alkalinity or Excess Base of Sea Water." Sears Foundation, Journ. Mar. Research, Vol. **8**, No. 1, pp. 14—20. New Haven, Conn., 1949.

R. P. Bell. "The Use of the Terms 'Acid' and 'Base'". Chem. Soc., Quart. Reviews, Vol. **1**., pp. 113—125. London, 1947.

In 1923 J. N. Brönsted and T. M. Lowry proposed almost simultaneously a new definition of acids and bases which reads: *An acid is a species* (of chemical substance) *having a tendency to lose a proton, and a base is a species having a tendency to add on a proton.* This can be expressed in the scheme $A \rightleftharpoons B + H^+$, where A and B are termed a conjugate acid-base pair. A must always be more positive than B by one unit of charge but otherwise there is no restriction on the sign or magnitude of the charge on either. The symbol H^+ here represents the bare proton and not the "hydrogen-ion" formed by the addition of a proton to a molecule of solvent, e.g., H_3O^+.

This definition has become widely accepted by academic physical chemists and now forms the basis of teaching of acid-base chemistry in most universities. It has not been accepted by many working on the borderlands of chemistry, of which one is oceanography. For this there have been good reasons. To anyone brought up on the classical ideas of what constitute acids and bases, largely the ideas of Arrhenius and Ostwald, the newer definition seemed cumbrous and unnecessary, no more than hair-splitting. It appeared that adequate and complete descriptions of the physico-chemical behaviour of the dissolved substances in sea water could be given in terms of classical theory.

Chemical oceanographers anticipate that their publications will be read not by fellow chemists but by biologists and physicists whose basic training has not been chemical. The chemists have been tempted to write in language which they hoped would be intelligible to most of their colleagues and not in a "new-fangled" one which they knew would not. This has been especially so in publications on the alkalinity of sea water and the carbonate equilibrium. The result has been some unnecessary statements which may be misleading.

The passage of time has shown that the Brönsted-Lowry definition provides a much more satisfactory explanation of acid-base phenomena, especially in non-aqueous solvents, and has stimulated much profitable investigation. Thus, the chemistry of the amino-acids has become much more

intelligible in terms of "zwitterions" or hermaphrodite ions, which are a necessary development from the Brönsted-Lowry definition.

In our own field, Rakestraw has now said forcibly what others, including the reviewer, might have said earlier if they had had the wit. He has martialled a number of statements made by outstanding authorities, has shown the intellectual difficulties to which they lead, and suggests the change that is necessary. This cannot fairly be presented in a few lines. The usual equation for excess base is:—

$$A = [HCO_3'] + 2[CO_3''] + [H_2BO_3']$$

This has been read as saying that the strong bases, Na^+, K^+, Mg^{++}, Ca^{++}, and Sr^{++}, exceed the strong acids, Cl', Br', and SO_4'', by an amount A which is equal to the sum of the chemical equivalents of the bicarbonate, carbonate, and borate ions. On the newer view, this equation becomes an exact definition of what we *mean* by excess base. It is quite unnecessary to consider the so-called excess of cations.

We have had here a pretty paradox which arises, not from the new definition, but from the old. Sodium hydroxide, when dissolved in water, dissociates into a cation, Na^+, and an anion, OH'. Sometimes the basicity has been attributed to the hydroxyl-ion, particularly when the scales of pH and pOH are in mind; at others it has been attributed to the alkali cation. Since base cannot be set off against base, both views cannot be right. The paradox is resolved by adopting the newer definitions of acid and base.

On p. 17, l. 17, of Rakestraw's paper, there is an unfortunate misprint; "cations" should read "anions".

Rakestraw's paper is not mere pedantic word-splitting. Words are as much the necessary tools of the oceanographer as are his ships and his instruments. No one would question his right to seek ships and instruments better suited to his purpose, yet it is just as necessary that the language in which he does his thinking and conveys his thoughts to others should be of the best.

Rakestraw has argued his case well but naturally has not felt able to spend paper on the presentation of knowledge accepted as commonplace by physical chemists. None the less only a complete presentation of the modern concepts of acid-base equilibria is likely to convert the sceptic. It is necessary to have a lively picture of what "tendencies to lose and add on protons" really mean in practice. A recent and masterly review of the whole subject by a student of Brönsted's is all the more welcome. Bell sets out the newer definition against its historical background and develops it in all its implications. For non-chemists this may provide the introduction which Rakestraw's paper needs if it is to succeed in its purpose.

The carbonate system is not the best on which to base a plea for a change. There are others much better. We have still much to learn of the distribution of amino-acids, alkylamines, alkylamine oxides, urea and other nitrogenous bases in sea water, and of their assimilation by plants, particularly in the tropics. According to the Brönsted-Lowry definition, these substances are neutral bases which can add on a proton to become acids:—

RNH_2	+	H^+	$\rightleftharpoons$	RNH_3^+
base	+	proton	$\rightleftharpoons$	acid

This simple concept is more likely to be experimentally fruitful, particularly

in studies of the physiology of assimilation, than the older one involving a mythical hydroxide whose existence has never been proved:—

$$RNH_3OH \rightleftharpoons RNH_3^+ + OH^-$$

Again, there is much that is odd and conflicting about our knowledge of the behaviour of silica dissolved in sea water. Hydrated silica possesses the power to build up branched and bridged chains of indefinite length. In sea water every combination is possible between metasilicate-ion and an electro-negatively charged piece of silica gel visible to the eye. Silica, crystalloidally or colloidally dissolved or dispersed in sea water, is best regarded as a negatively charged strong base with a strong tendency to add on protons. This concept, which closely describes what happens, is much more likely to be fertile than that of a weak acid, subject to unpredictable hydrolysis and giving no firm dissociation constant.

It may be as well to conclude with some examples of the changes in nomenclature that are called for:—

Example	Old name	New name
H_3O^+ (hydrogen-ion)	—	Acid
HCl (undissociated)	Acid	Acid
H_2CO_3 (undissociated)	Acid	Acid
Cl^-	Acid radical	Base
HCO_3'[1])	Acid radical	Base
OH^- (hydroxyl-ion)	Base?	Base
HCO_3''[2])	Acid radical	Acid
Na^+	Basic radical	Acid (very weak)
NH_4^+	Basic radical	Acid
NH_3	Base	Base
NH_4OH	Base	(unnecessary)
NaOH (undissociated if it exists so)	Base	Base (but better avoided)

Neutral water like the bicarbonate anion can both lose and add on a proton:—

H_2O	—	H^+	⟶	OH'
acid		proton		base
H_2O	+	H^+	⟶	H_3O^+
base		proton		acid.

It is because of this last reaction and no other that the hydrogen-ion is considered an acid.

It would seem that in many fields the Brönsted-Lowry definition is clearer and more likely to lead to advance than the older one. Cannot chemical oceanographers accept Rakestraw's plea and agree to march with their physico-chemical brethren?

L. H. N. Cooper.

---

[1]) In the reaction:

HCO_3'	+	H^+	⇌	H_2CO_3
base		proton		acid

[2]) In the reaction:

CO_3''	+	H^+	⇌	HCO_3'
base		proton		acid

W. B. Stockman. "A Theory of T-S Curves as a Method for Studying the Mixing of Water Masses in the Sea." Journ. Mar. Research, Vol. **6**, No. 1, pp. 1—24, figs. 1—9. Nev Haven, Conn., 1946.

H. Stommel. "Note on the Use of the T-S Correlation for Dynamic Height Anomaly Computations. Ibid., Vol. **6**, No. 2, pp. 85—92. New Haven, Conn., 1947.

During the 16th meeting of Scandinavian Naturalists in Kristiania (Oslo) in 1916 Helland-Hansen first demonstrated the temperature-salinity diagram, now so well known and so much in use. Since 1916 numerous authors have used the T-S representation in Physical Oceanography and interpreted the T-S curves. These curves are useful for the critical examination of observational data, presenting an effective means of unveiling erroneous observations. They are useful also for identifying and comparing characteristic water masses. In 1927 J. P. Jacobsen showed how they could be used for determining the "Vermischungs-Koeffizient", and in 1938 Okada developed the method further.

Stockman, in his paper, studies the vertical mixing in the case of three water-layers of which the intermediate one is limited. It then appears possible to develop definite rules concerning the triangle of mixing in the T-S system. These rules are valuable for the correct interpretation of the curves. But of still greater value is the result concerning the determination of the coefficient of convectivity. As will be remembered, the method of Jacobsen involves drawing a tangent to a T-S curve at the point of its maximum curvature. Those who have applied the method will have been aware of a serious difficulty, due to the fact that the maximum curvature varies with the scaling of the co-ordinates. Through Stockman's paper, this difficulty is now completely eliminated. As, however, the ideal conditions considered in theory are hardly found in nature, the determination of convectivity still remains difficult.

Stommel in his paper tries to determine "in the case where only temperature data are available (bathythermograms), whether or not it is possible to use the known T-S correlation for a given water-mass to supply information on salinity which is sufficiently accurate to be used in dynamic height and current computations." He finds that this is only possible in certain restricted regions and for rough dynamic computations. His discussion of the "interpolation error" is interesting, but hardly strictly correct.

Håkon Mosby.

J. M. Dunbar. "The State of the West Greenland Current up to 1944." Journ. Fish. Research Board Canada. Vol. **6**, No. 7, pp. 460—471. Toronto, 1946.

This paper contains 20 series of temperature measurements carried out by the author between February 1942 and September 1944 at a station at the mouth of Godthåb fjord, in West Greenland. Most of the records do not exceed 75 metres, but in 2 or 3 cases temperatures down to 200—300 m. were recorded. These records, probably the first to provide material for a study of the annual cycle of the sub-surface temperatures in these waters, are discussed by the author, who finds that the temperature decreased through these three years, especially in the first half of the year.

Three temperature series recorded by the author from more northerly localities are compared with earlier records, and the author arrives at the conclusion that warmer conditions existed during the decade from 1880 and were followed by a colder period up to about 1920, when a second warm period began, which culminated in the middle of the 1930's.

The author can have had no knowledge, owing to the war, of Kiilerich's more comprehensive work published in 1943[1]), but their conclusions are in fairly good agreement. Kiilerich states, that a warm period commenced in the 1880's, which prevailed to, or was again present in, 1895. A cold period commenced in the beginning of this century and lasted until a new warm period began in 1926 and culminated in 1934.

H. T.

Robert O. Reid. "The Equatorial Currents of the Eastern Pacific as Maintained by the Stress of the Wind." Journ. Mar. Research, Vol. **7**, No. 2, pp. 74—99. New Haven, Conn., 1948.

Ekman's explanation (1906) of the equatorial currents was fully accepted until 1932, when Sverdrup took up the same problem. A number of papers appeared in the following years, which in the end supported Ekman's general views. But in 1940 and after the last war, different authors have tackled the problem of deducing the equatorial currents from average wind conditions. Reid's paper contains a further development of Sverdrup's ideas from 1947 and presents a valuable contribution to the treatment of this rather special, but fundamentally very important, oceanographical subject. During the Assembly of the International Union of Geodesy and Geophysics at Oslo, in 1948, Sverdrup treated the problem anew and showed that in the western Pacific account would have to be taken also of lateral friction. At present several authors are active within this particular section of the research front, and it is hoped that a broad discussion may be taken up during the next Assembly of the I. U. G. G. at Brussels in 1951.

Håkon Mosby.

O. Paulsen†. "Observations on Dinoflagellates." (Edited by J. Grøntved). Kong. Danske Vid. Selsk., Biol. Skr., **6**, no. 4, 67 pp., 30 figs. København, 1949.

Ce travail ne représente qu'une partie d'un manuscrit posthume du regretté Professeur Paulsen. Tel qu'il est, limité à quelques genres et espèces, il sera indispensable à tout chercheur dans le groupe difficile des Dinoflagellés, car il comporte une revue critique de la classification et une bibliographie excellente.

Examinant les ouvrages de systématique (Lebour, Kofoid, Lindemann, Lefèvre, Schiller), l'auteur conclut que la subdivision simple de Lebour en 10 familles est préférable à celle de Lindemann en 14 familles et de Schiller en 21: tant que la structure d'un groupe est mal connue, il est nuisible de multiplier ses sections sans bases suffisantes. Ensuite, Paulsen étudie les causes ou critères invoqués au sujet de la grande

[1]) A. Kiilerich. "The Hydrography of the West Greenland Fishing Banks." Medd. fra Komm. for Danmarks Fisk.- og Havunders., Serie: Hydrogr., Bind III, Nr. 3. København, 1943.

variabilité de forme des espèces. L'explication de Schiller (milieu oligotrophe favorisant l'allongement des cornes ou ailes) est trop théorique: tous les facteurs de ces changements ne sont pas élucidés.

La sexualité étant rare ou nulle ici, la notion d'espèce devient plus arbitraire, et les critères habituels (interfécondité entre races géographiques) ne sont plus valables. Paulsen est donc d'avis de séparer franchement les formes voisines si elles sont isolées dans des aires distinctes: exemple *Peridinium crassipes* Pauls. et *P. curtipes* Pauls. La représentation des variations par polygones de fréquence est recommandée, et illustrée par les cas de *Dinophysis islandica* n. sp. et de quelques *Peridinium*. Ce dernier genre est ensuite subdivisé, selon les vieilles sections de Jørgensen 1913, mais en y distribuant les espèces d'une autre façon que Schiller. L'exemple difficile des *P. ovatum* (Pouch.) et *globulus* Stein est analysé. L'auteur compare les *Peridinium* à des plantes supérieures asexuées, comme les *Taraxacum*, qui ont pourtant une centaine d'espèces valables, localisées dans les diverses régions d'Europe.

Enfin, plusieurs *Dinophysis*, *Phalacroma*, *Goniaulax*, sont brièvement revus. En plus des plaques ventrales, sur lesquelles Paulsen insiste, il semble qu'une meilleure classification devra tenir compte de la cytologie interne, comme Chatton l'a bien montré pour les Dinoflagellés inférieurs.

F. B.

R. S. Wimpenny. "The size of diatoms. II. Further observations on *Rhizosolenia styliformis* (Brightwell)." Journ. Mar. Biol. Assoc. Vol. **26**, No. 3, pp. 271—284, 2 figs., 5 pl. Cambridge, 1946.

Material from the Antarctic, the subtropical Atlantic and Pacific Oceans, as well as from the North Sea and adjacent waters, have been used for diameter measurements and taxonomical studies of the *Rhizosolenia* population, especially *Rh. styliformis*. Two new varieties, *oceanica* and *semispina*, have been set up besides the type of this species, and their taxonomical affinities and distribution have been discussed. The author suggests that in the future the type species of *Rh. styliformis* as well as its variety *semispina* may be included in *Rh. hebetata* Bailey, while variety *oceanica* may have to be raised to specific state. Further material is needed, however, before this step can be taken.

Var. *oceanica* has not been recorded from the southern North Sea and its distribution indicates that it may be an indicator of oceanic water.

Continued studies of the variations in diameter of the *Rhizosolenia* population suggest that in the southern North Sea a period of 3—4 years elapses between the production of auxospore generations while in other areas such intervals do not seem to exceed one year.

It is to be hoped that observations of the *Rhizosolenia* populations along the lines of this investigation may be continued, since interesting taxonomical and biological problems may then be clarified.

T. B.

D. P. Wilson. "The triradiate and other forms of *Nitzschia closterium* (Ehrenberg) Wm. Smith, forma *minutissima* of Allen and Nelson." Journ. Mar. Biol. Assoc. Vol. **26**, No. 3, pp. 235—270, 9 figs. Cambridge, 1946.

The *Nitzschia* species isolated by Allen and Nelson in 1907 and since kept in culture at the Marine Biological Laboratory in Plymouth has been extensively used for botanical studies and as a food organism for marine

animals. It is generally named *Nitzschia closterium*. The present paper reports on morphological studies of the various types to be found in culture, especially the triradiate, the oval, the cruciate forms, and the normal two-armed form.

The cell wall was found to be very lightly silicified, a feature which makes it possible for the cells to elongate without auxospore formation, which never was observed in culture.

Subcultures of clones of normal and of triradiate forms remained true to type for some months, except for producing oval cells. After half a year the other forms occurred in both clones, although infrequently, but they gradually increased in number. When triradiate forms are present, they may multiply faster than normal cells and almost completely dominate the cultures. On the other hand a proportion of triradiate cells may, during successive divisions, pass into normal condition, and there is a tendency under unfavourable conditions for triradiates to be eliminated.

The occurrence of triradiate forms in nature is recorded in several definite cases, a fact which shows that it does not represent an abnormal culture form.

The cruciform type which occurred occasionally in several cultures appeared to be somewhat unstable, though persisting for a long time.

There is some doubt about the taxonomical status of this *Nitzschia* species, but the author proposes to retain Allen and Nelson's name until a closer study is made of the whole genus.

Nitzschia closterium cultures have been so generally used for botanical work that this study of its morphology and variability is most welcome. Its virtues as a laboratory organism, its resistance and adaptability, are paralleled by its morphological variability. A physiological study might reveal similar features. So far, it seems obvious that observations on its physiology are not at all characteristic of marine plankton diatoms in general and one may wish that more representative planktonic diatom species may be subjected to physiological studies in future.

T. B.

Mary Sears. "Note on the phytoplankton on Georges Bank in 1940." Journ. Mar. Research, Vol. **4**, No. 3, pp. 247—257, figs. 55—58. New Haven, Conn., 1941.

In order to supplement previous studies of the phytoplankton of Georges Bank, especially during spring, samples were collected on five cruises from late March to the end of June, 1940, at the following levels: 1, 10, 30, 50, and 80 m. The spring diatom flowering was found to be approaching its height during the latter part of March, reaching its climax about mid-April and then gradually decreasing. A moderately active production took place also during the months of May and June, since the period of diatom abundance lasted longer here than in the rest of the Gulf of Maine.

Species of *Chaetoceros* characterized the plankton, *Ch. decipiens* being predominant in early spring, *Ch. debilis* and *compressus* during the latter part. In June *Leptocylindrus minimus* occurred in vast numbers, forming as much as 34 % of the population by number.

On the basis of estimates of volumes of the more important species it is suggested that Georges Bank is one of the more productive areas of the gulf.

T. B.

G. A. Riley. "Plankton Studies. IV. Georges Bank." Bull. Bingham Oceanogr. Collect. Vol. **7**, Art. 4, pp. 1—73, 4 figs. New Haven, Conn., 1941.

The author's Plankton Studies IV comprises two parts: 1) a comparison between plant pigment and chlorophyll content, the number of cells, cell volume, dry weight, and the weight of organic matter and ash in quantitative net hauls from Georges Bank at various seasons; 2) a study of the vertical and horizontal distribution of plant pigments, nitrate, phosphate, and oxygen in the same region on six cruises between September 1939 and July 1940.

From the comparison between plant pigment and the other measurements of the phytoplankton it was found that plant pigment had the highest mean correlation with other types of measurements and therefore was the most nearly representative determination of phytoplankton. Conversion factors from one type of plankton determination to another are represented.

The author points out that the plant-pigment method is chosen in order to study the relations of the plant population as a whole to its environment.

Georges Bank, well known from B i g e l o w's classical plankton studies, is a most interesting area, moderately shallow, oceanic, and with characteristic currents and eddies. Considerable vertical turbulence was found to take place during January, March, and April down to a depth of at least 100 m., while during the remainder of the cruises a well established discontinuity layer was recorded, except for the shallowest parts of the bank.

The spring diatom outburst probably began in March and lasted until May, starting in shallow water, where it also lasted longer than in the surrounding deeper waters. The pigment values did not, however, reach very much higher values in the shallow part than in the deeper. During summer, plant pigment was found to occur in moderately large concentrations in the upper 30—50 m. of the north-central part of the bank, extending north-east and south-west of the central portion. The concentration decreased gradually towards deeper water on the sides of the bank. The total quantity underlying a unit area was, however, not markedly greater in the shallow than in the deeper parts. During winter (January) the quantity of plant pigments was less than at any other time and mainly concentrated in the surface layers, the horizontal distribution being fairly uniform.

Variations in the oxygen percentage and in the oxygen liberation in experiments according to G r a n's method were similar to those of plant pigments. The largest concentrations of nitrate and phosphate during the summer months were in the shallow water. During winter, phosphate and nitrate occurred in large quantities, consumption being evident during the spring diatom development, this again being followed by an increase in May, probably associated with an influx of off-bank water.

The characteristic hydrographical features seem to be responsible for the remarkable positive correlation between plant pigments and nutrients during summer, while otherwise the predominant relation was the usual negative one.

The seasonal cycle is discussed, stress being laid upon solar radiation and vertical transport by turbulence as limiting factors during the darker part of the year, and nutrients, grazing, and high temperature during the other seasons.

The mean standing crop of plankton was estimated at from 2 to 39 g. of carbon per $m.^2$ of sea surface. The total productivity of the bank is considered to be little more than that of the surrounding waters, while the larger concentration of phytoplankton on the bank is believed to be of ecological importance for the fauna.

T. B.

G. A. Riley. "The relationship of vertical turbulence and spring diatom flowerings." Journ. Mar. Research, Vol. **5**, No. 1, pp. 67—87, figs. 24—29. New Haven, Conn., 1942.

The spring flowering of diatoms on Georges Bank (Gulf of Maine) was studied on four cruises, the population being characterized by Harvey plant-pigment units. The material is subjected to an interesting analysis of the relationship between stability and rate of increase in population. The observations corroborate the view set forth by Gran and Braarud (1935) and Steemann Nielsen (1935), and the author elaborates the influence of the stability factor in his theoretical discussion. Assuming the thickness of the euphotic zone and the rates of photosynthesis and respiration to be constant, the rate of increase in the plankton population is found to be a linear function of the reciprocal of the thickness of the zone of vertical turbulence. The Georges Bank observations from the April cruise fit this theory. Although factors like grazing and sinking enter in, the author finds support for the statement that these factors do not change considerably during the spring development and that consequently the rate of photosynthesis of the population is the decisive factor for the changes in the plant pigment. He stresses, however, our inadequate knowledge of the grazing phenomenon and the physiological properties of the diatoms.

T. B.

B. G. Bogorov. "Peculiarities of Diurnal Vertical Migrations of Zooplankton in Polar Seas." Journ. Mar. Research., Vol. **6**, No. 1, pp. 25—32, 10 figs, tables 1 and 2. New Haven, Conn., 1946.

In this paper the author compares the behaviour of certain plankton animals in polar seas in summer and autumn. During the summer in high latitudes there is continuous daylight, but in the autumn there is alternation from light to darkness during the twenty-four hours.

It was found that in the Barents Sea the dominant species showed no change in their vertical distribution during the twenty-four hours. In fact, owing to the tidal cycle, it must have been necessary for the animals to migrate vertically to maintain their level in the water. In the Barents and Kara Seas in September, however, there was a considerable increase in the numbers of animals in the surface layers at night. To confirm these observations collections were made in October in the Barents Sea, modestly described as "quite an achievement considering the weather conditions present in the autumn."

Two species, *Oithona similis* and *Oithona plumifera,* showed no vertical movements in summer or autumn.

The above observations provide evidence supporting the theory that light is a dominating factor controlling the vertical distribution of many plankton animals.

F. S. R.

J. H. Fraser. "The Distribution of Thaliacea (Salps and Doliolids) in Scottish Waters 1920 to 1939." Scottish Home Dept., Fisheries, Sci. Invest., 1949, No. 1, pp. 1—44, figs. 1—16, tables I—IV. Edinburgh, 1949.

Two facts which have detracted from the usefulness of the theory of animal indicators are that few animals are clear-cut as to their environmental conditions, and that in general there has been a tendency to create varieties of species based only on geographical position. Where there is a mixture of two such varieties (and the planktologist has to deal often with immature forms), or a possibility of such a mixture, the interpretation of the hydrographical conditions by this means becomes extremely uncertain. Dr. Fraser is happy in the choice of his subject in that the Thaliacea are an exception to both these facts and their presence in waters off the British coasts is alone sufficient evidence of a warm Atlantic influx (water of salinity 35·0 $^{0}/_{00}$ or over). Data provided by the author support in addition the suggestion that both salps and doliolids undergo a vertical migration and that the majority of individuals are to be found in currents well below the actual surface. They, therefore, have the additional advantage of providing evidence for the interpretation of the hydrographical conditions in a layer relatively unaffected by wind, and where these cannot be followed directly by the use of drift-bottles.

The various species found and their influxes have been investigated in Scottish waters throughout the years 1920 to 1939, their actual numbers being dependent on (a) the strength of the Atlantic influx; (b) its temperature, which may allow or prohibit reproduction in transit; (c) the plankton content of the area from which the influx originates, variation in which suggests that Atlantic water may originate in different years from different parts of the ocean.

Material for the study was not collected specially, there being, therefore, gaps in the information for particular areas and particular times. In most cases the collections were made by a standard method throughout of ¼-hour hauls with three 1-metre cheese-cloth nets (25 meshes to the inch) towed at the surface, 50 metres, and 100 metres depth respectively.

From the biological evidence it is shown that the course and indirectly the strength of the Atlantic influx agrees closely with that from the hydrographical data, viz. (a) the main influx into the northern North Sea travels round the north and east of Shetland as a stream current which usually lies well off the Shetland coast; (b) there is no appreciable influx between Fair Isle and Shetland, this area being affected by water from the east side of Shetland later in the year than the north of Scotland; (c) there is some influx immediately north of Orkney which may affect the Moray Firth, but not the southern Moray Firth, and only rarely the North Sea proper. This area is affected earlier in the year than the invasion of the Fair Isle district.

On pp. 27—28, there is a review of the plankton records of F. S. Russell, etc., in emphasis of a different plankton content of the English Channel and Scottish influxes of Atlantic water, and Fraser interprets the data to show that these never occur together. This supports Carruthers, who infers that there is only a flow through the Straits of Dover into the North Sea from the English Channel when there is little Atlantic pressure into the Scottish area. It should be pointed out, however, that the paper of Hardy, Carruthers, and Lumby (1923) which Fraser quotes in support really consists of three separate papers and that, while

both Hardy and Lumby regard 1920 and 1921 as years of high Atlantic content in the North Sea, Lumby expressly mentions the Seven Stones as being remarkable because it was the only position which showed a low salinity. Lumby's data for 1920 and 1921 do not in fact support Carruthers' hypothesis and this is made plainer by reference to two papers of his which Fraser apparently has not consulted. Lumby[1]) states: "In the early summers of 1921 and 1922 water of unusually high salinity entered the English Channel. Part of this water, which may have originated from the Mediterranean" [*D. gegenbauri* was thought originally to be confined to this area], "moved as a subsurface current through the Channel and appeared on the surface at the eastern end of the Channel, ultimately passing through Dover Straits into the Southern Bight."

Lumby[2]) shows a table of the mean annual surface temperatures and salinity of the English Channel generally which depicts a high salinity over the period 1920—1922 and a particularly high temperature in 1921.

Fraser calls attention to the fact that the asexual phase can produce enormous numbers of sexual forms in a short time, and that these under favourable conditions populate the waters with a large number of *small* salps or doliolids in contrast to the fewer *larger* individuals that have themselves been carried into the area by the North Atlantic Drift. The mere presence of these sexual forms alone without supporting hydrographical evidence cannot be taken, however, to indicate large Atlantic influxes into the North Sea as he suggests as probable for 1925 (salps) and 1928 (doliolids) In October 1947, for instance, there were large numbers of doliolids of the sexual form present in the North Sea off the coast as far south as 55° 53′ N., but as Dr. Fraser has himself told me from evidence elsewhere there was no specially large Atlantic influx in that year. The numbers in the North Sea had their origin from relatively few specimens which finding the surface waters themselves abnormally warm were able to breed rapidly. In fact in no place where I recorded doliolids was the salinity above 34·68 $^0/_{00}$.

Neither can I agree — at any rate, so far as my experience in the North Sea is concerned — with his statement on p. 29, that if the conditions favour a great production of small salps (or doliolids) they will develop largely to the exclusion of other macroplankton, especially the crustacea. In October 1947 at one station off the Northumberland coast, I have recorded in a single vertical haul of the Hensen net 7,650 sexual forms, 300 tailed larvae, and 600 asexual forms of *Dolioletta gegenbauri* representing 287, 11, and 22 respectively per cubic metre. The total number of this doliolid was only exceeded by either salps or doliolids from the Scottish collections between 1922—1939 on four occasions by the three 1-metre nets combined. Neither at the station mentioned nor at neighbouring stations where doliolids were recorded did the composition of the remaining members of the zooplankton differ from other years, and crustacea were present in usual numbers. There is cause to doubt, therefore, whether the presence of a thriving population of salps or doliolids could cause a great loss to broods of young plankton-feeding fishes hatching in such waters.

It is to be noted that Fraser refers on p. 3 to Tait (1937). Such a paper is not given in his list of references.

J. G. Cattley.

---

1) J. R. Lumby. "The Salinity and Water Movements in the English Channel and Southern Bight during the Period 1920—1923." Min. of Agric. and Fish., Fish. Invest., Ser. II, Vol. VII, No. 7. London, 1925.

2) J. R. Lumby. "Salinity and Temperature of the English Channel." Min. of Agric. and Fish., Fish. Invest., Ser. II, Vol. XIV, No. 3. London, 1935.

Hilary B. Moore. "The zooplankton of the upper waters of the Bermuda area of the North Atlantic." Bull. Bingham Oceanogr. Collect., Vol. **12**, Art. 2, pp. 1—97, 208 figs. New Haven, Conn., 1949.

The present paper comprises a survey of the zooplankton of the upper 300 metres in the Bermuda area in the period 1938—1940. Owing to war conditions, it was not possible to make long cruises in 1940. Most of the collections were made from the Royal Society's ketch "Culver" and the medium silk closing net (70 cm. diameter) was used. The net was lowered open to the maximum depth and towed for half an hour at an estimated speed of two knots. The procedure of fishing was as follows:— The net was raised 10 metres vertically at the end of each five minutes, so that when it was closed by messenger at the end of thirty minutes it had fished representatively through a vertical distance of 50 metres. Catches were preserved in 4 % formaldehyde in water, neutralized with borax, and the volume of each sample was estimated by washing onto silk, draining for one minute, and then washing with a known quantity of water into a measuring cylinder.

In the material collected the following groups have been worked up:— coelenterates, chaetognaths, pteropods & heteropods, copepods, euphausids, amphioxides, and tunicates. Details of the occurrence of the various species belonging to these groups have been given, and for the more abundant forms graphs show the seasonal variations in numbers and vertical distribution. Small charts illustrate seasonal changes in horizontal distribution. Other graphs give the relation of night surface abundance to phase of moon, the relation of mean day level to cloudiness of sky and the diurnal migration. This systematic survey contains a large number of observations of the greatest interest, but it is not possible here to go in details.

In September and December 1938 is was clearly shown that an area of richer zooplankton was found to the east of the islands and a poor area to the west. On the cruise in May 1939 the conditions were reversed, but in July the same year showed a return to conditions resembling those found the previous autumn. As a tentative hypothesis explaining these seasonal changes in distribution of zooplankton the author discusses the possibility of changes in the local current system round Bermuda and the occurrence of upwelling in this area.

Of more general interest it may be mentioned that it has been possible to show the influence of illumination, viz., the varying degrees of cloudiness, on the vertical distribution of the plankton as a whole. Further, it has been demonstrated that the illumination from the moon has a marked effect on the surface plankton, but the important question about diurnal migration has only been touched on as further work is in progress on this aspect. It is, however, of great interest to remark that in some cases the rate of ascent of several deeper forms, especially euphausids, is not sufficient to bring them to the highest level until well after midnight.

The present paper contains a lot of valuable information and it is to be hoped that there will be an opportunity of continuing and extending this interesting research.

Poul Jespersen.

H. B. Bigelow; I. P. Farfante; W. C. Schroeder. "Fishes of the Western North Atlantic." Part 1. Bigelow & Farfante: "Lancelets." Bigelow & Schroeder: "Cyclostomes." Bigelow & Schroeder: "Sharks." Sears Foundation for Marine Research, Memoir No. I, XVII + 576 pp., 114 text-figs. New Haven, 1948.

Any student of biological phenomena will sooner or later realize that the first tool he has to look for is a reliable handbook for identification of his specimens. This may not always be so obvious to the fishery biologist in Europe, who generally only deals with a fairly limited number of species, well known from time immemorial, viz., the herring, the cod, the halibut, etc. But one has only to call to mind the species of *Ammodytes* to admit that even amongst species very important to the North Atlantic fisheries we may still get surprising discoveries of great significance. One cannot but admire the audacity of several ichthyologists of the nineteenth century who, like Jordan & Evermann, ventured to write about all species from a vast area like North America, including both fresh and salt water, or even, like Guenther, ventured to give a descriptive catalogue of the fishes of the world. Since then an enormous amount of work has been laid down in thousands of papers, impossible for every single ichthyologist to have to hand, and in case he had access to them, impossible to handle. It has been felt for many years that we now badly need to have all these detailed studies worked up together in a critical way in close connexion with a new study of all collections available; but since our knowledge is very limited in many geographical areas it would be of little sense to contemplate a publication covering the whole world.

As an outstanding example of what could be done now, and certainly should be followed up with similar work as soon as possible elsewhere, this first part of "Fishes of the Western North Atlantic" is pretty near to the ideal. An Editoral Board of five prominent American ichthyologists has been formed, with Dr. John Tee-Van as the Editor-in-Chief, to publish an account of all fishlike creatures, from the lancelets to the true bony fishes, from the waters of Hudson Bay southward to the Amazon River. An Advisory Committee of nine more ichthyologists is assisting the editors; here Europe was represented by J. R. Norman until his untimely death in 1944.

When the present part is considered, it is hard to appreciate the immensity of the task that lies before the editors, and how many volumes must follow. Six species of lancelets, two cyclostomes, and sixty-two sharks are treated at a standard which has been formulated for the whole work, to include the distinctive characters, a detailed description, biology, range, relation to man, and the occurrence in the Western Atlantic, ending up with a very comprehensive list of synonyms and references of each single species. The descriptions are based on the material available for study, which is listed for each species, and it is remarkable that only two species of sharks have not been seen by the authors. Excellent illustrations, the great majority being original, follow the text, and once more it is realized how much superior a good drawing is to photographs. It is a great advance that all proportional dimensions are given as percentages of total length; one may hope that all ichthyologists will now abandon the old system of giving, for example, "head 3 to $3^1/_3$ in total length, eye $2^1/_5$ to 3 in head" etc., which, indeed, gives very poor information about the dimensions and is difficult to use for comparison. The metric system has been widely used, but not consistently;

it seems queer in a list of material to read: "Female, 830 mm., ...; male 429 mm. ....; male, 4 feet, ...; male, 1,167 mm., ..."; etc. It is obvious that the metric system has been omitted in the text to make the book more convenient to the sportsman and commercial fisherman, but scientists would have appreciated having all lengths and weights given in the metric system in brackets, as has been done in some scattered cases. This, however, is a very minor detail in comparison with the chief impression, that a combination of an immense number of original studies has been made, which together with all published data, is presented in very clear and concise language.

The scope of the book is much wider than merely to give descriptions of the species of the Western Atlantic. The characterizations of the orders, families, and genera cover the groups as a whole, and in some cases this applies to the species keys within the genera; this is naturally a most valuable addition and will make the book indispensable to any student of fishes wherever he lives.

The nomenclature is up to date according to the International Rules; again this will make many biologists sigh when, for instance, they have to give up *Lamna cornubica* for *Lamna nasus,* and a glance at the list of synonyms and references with its numerous quotations of *L. cornubica* against the few of *L. nasus* would form a good argument for having had the Rules suspended, so that Gmelin's name from 1789 could have been retained instead of Bonnaterre's from 1788. —

The type, paper, and binding are fully up to the high quality of the text, and are definitely in inverse proportion to the very low price of the book. It forms Memoir No. I from the Sears Foundation for Marine Research, hitherto so well known for its *Journal of Marine Research.* The income derived from the sales of the volume will be used for the production of the remainder of the publication. One can only wish then that the book may be sold and even get out of print very soon, as the best way to encourage the Editorial Board to continue the publication as quickly as possible. Dr. Henry B. Bigelow figures as senior author of all three papers in the present volume; it may safely be concluded that his skilled pen has contributed most essentially to its very high standard, which makes it rank amongst the masterpieces of ichthyological literature.

Anton Fr. Bruun.

Current Bibliography.

Prepared by the Editor with the Assistance of Mr. A. C. Simpson.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

Subscribers and those on the distribution list will receive regularly upon application to the General Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

1) General Oceanography.

1) a Expeditions.

Anon. "Campañas del 'Xauen' en 1947 y 1948 en el Mar de Alborán y en al Estrecho de Gibraltar". Bol. Inst. Español Oceanogr., **18**, Madrid, 1949.

Anon. "Station list R. R. S. 'William Scoresby', 1931—1938". Discovery Rep., **25**, pp. 143—280, Cambridge, 1949.

Pettersson, H. "The Swedish deep-sea expedition". Pacific Sci., **2**, pp. 231—8, Honolulu, 1948.

Pratje, O. "Die schwedische 'Albatross' Expedition 1947/48". Deutsch. Hydrogr. Zeitschr., **2**, 4, pp. 154—6, Hamburg, 1949.

Schubert, K., und Krey, J. "Die deutsche Ringwadenexpedition 1947 nach Island". Arch. f. Fisch. Wiss., 1 Jahrg., 3—4, pp. 186—7, Hamburg, 1949.

1) b Institutes.

Anon. "Jahresbericht Nr. 3, 1948". Deutsch. Hydrogr. Inst., Hamburg, 1949.

Anon. "Seventeenth annual report for the year ending 31 March, 1949". Freshwater Biol. Assoc., Ambleside, 1949.

Anon. "Annual report for 1948 (No. 61) of the Marine Biological Station at Port Erin, Isle of Man". Liverpool, 1949.

Anon. "Annual report and statement of accounts for the year ended 31 December 1948". Colonial Develop. Corporation, H. M. S. O., London 1949.

Anon. "Officers and executive Committee (1946—48), Scientific Committees (1946—48)". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 5—6, Bergen, 1949.

Church, P. E. "Postwar plans of oceanographic laboratories, University of Washington". Trans. American Geophys. Union, **27**, 4, p. 574, Washington, 1946.
Gall, J. le. "Rapport sur le fonctionnement de l'Office Scientifique et Technique des Pêches Maritimes pendant l'année 1945 –46". Rev. Trav. Office des Pêches Marit.. **14**, 1—4, pp. 9—24, Paris, 1948.
Pax, F. "Das Institut für Meeresforschung in Bremerhaven". Hydrobiologia, **2**, 1, pp. 94—6, den Haag, 1949.
Wilson, D. P. "Notes from the Plymouth aquarium". Journ. Mar. Biol. Assoc. U. K., N. S., **28**, 2, pp. 345—51, Cambridge, 1949.

2) Hydrography.

2) a Apparatus and Methods.

Anon. "The portable tide predicting machine". Internat. Hydrogr. Rev., **26**, 1, pp. 107—11, Monaco, 1949.
Buch, K., und Nynäs, O. "Die pH-Bestimmung des Wassers mit dem Photoelektrischen Kolorimeter und der Glaselektrode". Acta Acad. Aboensis, Math. et Phys., **13**. 4, Åbo, 1940.
Carruthers, J. N. "A new method of continuous current-measuring from an unattended buoy". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb.. 4, p. 130, Bergen, 1949.
Dahl, O., and Fjeldstad, J. E. "A new repeating current-meter". Assoc. d'Océanographie Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 131—2, Bergen, 1949.
Ford, W. L. "The field use of a salinity-temperature-depth recorder". Journ. Mar. Res., **8**, 1, pp. 84—96, New Haven, Conn., 1949.
Johnson, J. W. "Scale effects in hydraulic models involving wave motion". Trans. American Geophys. Union, **30**, 4, pp. 517—25, Washington, 1949.
Kalle, K. "A new method of measuring surface currents at sea from anchored ships". Deutsch. Hydrogr. Zeitschr., **1**, pp. 164—8, Hamburg, 1948.
Lundbak, A. "A new accurate burette for small volumes". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb., 4, pp. 144—5, Bergen, 1949.
Munk, W. H., Inglesias, H. V., and Folsom, T. R. "An instrument for recording ultra low frequency ocean waves". Rev. Sci. Instr., **19**, pp. 654—8, U. S. A., 1948.
Russell, R. D. "SOFAR: A new oceanographic research tool". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb., 4, p. 150, Bergen, 1949.
Spilhaus, A. "Bathythermograph sea sampler". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb., 4, pp. 146—7, Bergen, 1949.
Villagrazia, P. M. di. "Identificazione e determinazione rapida 'in situ' della salsedine delle acque col rifrattometro tascabile". Boll. Pesca, Piscicolt. e Idrobiol., **4**, 1, pp. 61—9, Roma, 1949.
Worzel, J. L. "Ocean bottom sampler for ships under way". Geophysics, **13**, 3, pp. 452—6, U. S. A., 1948.

2) b Surveys.

Alander, H. "Baltic Area. Hydrography. General". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 139—40, Copenhague, 1949.
Einarsson, H. "Influx of Atlantic water north of Iceland 1947". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 10—11, Copenhague, 1949.
Gilles, D. C. "The temperature and salinity of the surface waters of the Irish Sea for the period 1935—46". Monthly Not. Roy. Astr. Soc., Geophys. Suppl., **5**, 9, pp. 376—97, Edinburgh, 1949.
Glowinska, A. "The hydrography of the Gulf of Gdansk". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 142—3, Copenhague, 1949.
Hermann, F. "Hydrographic conditions in the Faroe-Shetland Channel in July 1947". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 8—9, Copenhague, 1949.
Jensen, A. J. C. "Hydrography at Bornholm". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 141—2, Copenhague, 1949.
Tait, J. B. "Scottish hydrographical investigations". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 60—3, Copenhague, 1949.
Thomsen, H. "Monthly mean of salinity and temperature at surface and bottom at the lightvessel 'Vyl' for a longer series of years, and anomalies from this mean in 1946—47". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, p. 89, Copenhague, 1949.
Thomsen, H. "Hydrography. Kattegat and Belts". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 125—6, Copenhague, 1949.

Tully, J. P. "Oceanography and prediction of pulp mill pollution in Alberni inlet". Fish. Res. Board Canada, Bull. 83, Ottawa, 1949.
Wallbrecher, G. O. "Estudios y trabajos oceanograficos en la Antartida". La Plata, Argentina, 1948.

2) c Chemistry of Sea Water.

Anderson, D. H., and Robinson, R. J. "Rapid electrometric determination of the alkalinity of sea water using a glass electrode". Industr. and Engin. Chem., **18**, p. 767, Easton, Pa., 1946.
Anon. "Nautical-Meteorological Annual, 1947". Publ. Danske Meteorol. Inst., København, 1949.
Anon. "Environment. Phosphate contents". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, p. 48, Copenhague, 1949.
Barnes, H. "Analysis of sea water". Ann. Rep. Chem. Soc., **45**, pp. 338—44, London, 1949.
Buch, K. "New determination of the second dissociation constant of carbonic acid in sea water". Acta Acad. Aboensis, Math. et Phys., **11**, 5, Åbo, 1938.
Buch, K. "Analytisk bestämning av extremt låga järnkoncentrationer med $\alpha = \alpha^1$: dipyridyl". Finska Kemistsamf. Medd., 1—2, Helsinki, 1942.
Buch, K. "Dithizonmetoden för bestämning av zink och koppar i naturliga vatten". Finska Kemistsamf. Medd., 1—2, Helsinki, 1944.
Buch, K., och Koroleff, F. "Jämviktsstudier rörande bly- och alkalidithizonater". Finska Kemistsamf. Medd., 3—4, pp. 98—110, Helsinki, 1945.
Buch, K. "Kolsyrejämvikten i Baltiska havet". Fennia, **68**, 5, Helsingfors, 1945.
Buch, K., und Ursin, M. "Zur Methodik der Bestimmung von Phosphor im Meerwasser". Merentut. Julk., 140, Helsinki, 1948.
Fond, E. C. la. "Thermal structure of the surface layers of the sea near the Antarctic convergence". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, p. 115, Bergen, 1949.
Hindman, J. C., Anderson, L. J., and Moberg, E. G. "A precise determination of chlorinity of sea water using the Ag — AgCl indicator electrode". Journ. Mar. Res., **8**, 1, pp. 30—5, New Haven, Conn., 1949.
Koczy, F. F. "Thorium in sea water and marine sediments". Geol. Fören. Stockholm, Förhand., **71**, 2, pp. 238—42, Stockholm, 1949.
Koroleff, F. "Determination of manganese in natural waters". Acta Chem. Scandinavica, 1, pp. 503—6, Helsinki, 1947.
Lieber, M., and Eliassen, R. "The use of the amidol test for dissolved oxygen in sea water". Journ. Mar. Res., **8**, 2, pp. 107—19, New Haven, Conn., 1949.
Nümann, W. "Kolorimetrische Bestimmung von Silikat, Phosphor und Stickstoff im Meerwasser". Deutsch. Hydrogr. Zeitschr., **2**, 4, pp. 137—53, Hamburg, 1949.
Rakestraw, N. W. "The conception of alkalinity or excess base of sea water". Journ. Mar. Res., **8**, 1, pp. 14—20, New Haven, Conn., 1949.
Redfield, A. C. "Characteristics of sea water". The Corrosion Handbook, pp. 1111—22, New York, 1948. (Contrib. No. 394 Woods Hole Oceanogr. Inst.).
Urick, R. J., and Searfoss, L. W. "The microthermal structure of the ocean near Key West, Florida. Pt. 1, Description". Naval Res. Lab. Rep. S-3392, Washington, 1948.

2) d Physical Properties.

Anon. "Nautical-Meteorological Annual, 1947". Publ. Danske Meteorol. Inst., København, 1949.
Bauer, L., Tamerkin, P., and Lindsey, R. B. "The scattering of ultrasonic waves in water by cylindrical obstacles". Journ. Acoust. Soc. America, **20**, pp. 858—68, Menasha, Wis., 1948.
Bowden, K. F. "The process of heating and cooling in a section of the Irish Sea". Mon. Not. Roy. Astron. Soc., **5**, pp. 270—81, London, 1948.
Dietz, R. S. "Deep scattering layers in the Pacific and Antarctic Oceans". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, p. 149, Bergen, 1949.
Eyring, C. F., Christensen, R. J., and Raitt, R. W. "Reverberation in the sea". Journ. Acoust. Soc. America, **20**, pp. 462—75, Menasha, Wis., 1948.
Liebermann, L. N. "Reflection of sound from coastal sea bottoms". Journ. Acoust. Soc. America, **20**, 3, pp. 305—9, Menasha, Wis., 1948. (Contrib. No. 433 Woods Hole Oceanogr. Inst.).

Liebermann, L. N. "Reflection of underwater sound from the sea surface". Journ. Acoust. Soc. America, **20**, 4, pp. 498—503, Menasha, Wis., 1948. (Contrib. No. 455 Woods Hole Oceanogr. Inst.).
Redfield, A. C. "Characteristics of sea water". The Corrosion Handbook, pp. 1111—22, New York, 1948. (Contrib. No. 394 Woods Hole Oceanogr. Inst.).

2) e Temperatures.

Dannevig, A. "Hydrography. Norway coast of Skagerak". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, p. 125, Copenhague, 1949.
Legrand, J. "Nouvelles preuves du rôle de l'échauffement progressif de la mer dans l'affaissement apparent des côtes septentrionales de l'Europe". Comptes Rendus, Acad. Sci., **210**, pp. 540—2, Paris, 1940.
Roll, V. "Eine scheinbare Anomalie der Temperaturdifferenz Luft-Wasser". Deutsche Hydrogr. Zeitschr., **2**, 4, pp. 134—7, Hamburg, 1949.
Smed, J. "Monthly anomalies of the surface temperature in the sea round Iceland during the years 1876—1939 and 1945—1947". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 11—26, Copenhague, 1949.
Smed, J. "Monthly anomalies of the surface temperature in areas of the northern North Sea". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 57—60, Copenhague, 1949.
Smith, O. R., and Ahlstrom, E. H. "Echo-ranging for fish schools and observations on temperature and plankton in waters off central California in the spring of 1946". U. S. Fish and Wildlife Serv., Spec. Sci. Rep., 44, Washington, 1948.
Wahl, E. "Temperaturmessungen in der Nordsee im Sommer 1948". Ann. Meteorol., 2 Jahrg., 3—4, pp. 65—71, Hamburg, 1949.

2) f Submarine Illumination.

Seiwell, H. R. "Oceanographic factors in underwater depth determination by aerial photography". Photogram. Engin., **15**, pp. 171—6, ?, 1949.

2) g Hydrodynamics.

Arons, A. B., and Halverson, R. R. "Hydrodynamic properties of sea water at the front of a shock wave". Journ. Chem. Phys., **15**, pp. 785—93, Lancaster, Pa., 1947.
Hidaka, K. "Mass transport in ocean currents and lateral mixing". Journ. Mar. Res., **8**, 2, pp. 132—6, New Haven, Conn., 1949.
Proudman, J. "The theory of mixing of sea-water through turbulence". Proc. Roy. Soc., **195**, pp. 300—9, London, 1948.

2) h Currents and Oceanic Circulation.

Anon. "Nautical-Meteorological Annual, 1947". Publ. Danske Meteorol. Inst., København, 1949.
Barnes, C. A., Bumpus, D. F., and Lyman, J. "Ocean circulation in Marshall Islands area". Trans. American Geophys. Union, **29**, 6, pp. 871—6, Washington, 1948. (Contrib. No. 420 Woods Hole Oceanogr. Inst.).
Becker, R. "Kraftantrieb und Leistung des Windes an der Meeresoberfläche". Deutsche Hydrogr. Zeitschr., **2**, 4, pp. 125—9, Hamburg, 1949.
Bowden, K. F., and Proudman, J. "Observations on the turbulent fluctuations of a tidal current". Proc. Roy. Soc., Ser. A, **199**, 1058, pp. 311—27, London, 1949.
Ekman, V. W. "Turbulent, periodic and mean motions: some measurements in the Atlantic by B. Helland-Hansen and the author". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 139—41, Bergen, 1949.
Guelke, R. W., and Schoute-Vanneck, C. A. "The measurement of sea-water velocities by electromagnetic induction". Journ. Inst. Elect. Engin., **94**, pp. 71—4, London, 1947.
Hidaka, K., and Suzuki, T. "On the secular variations of Tsusima current". Geophys. Notes, Tokyo Univ., 38, Tokyo, 1948.
Hidaka, K. "Depth of motionless layer as inferred from the distribution of salinity in the ocean". Trans. American Geophys. Union, **30**, 3, pp. 346—8, Washington, 1949.
Iselin, C. O'D. "Preliminary report on long-period variations in the transport of the Gulf Stream system". Pap. in Phys. Oceanogr. and Meteorol., **8**, 1, Cambridge, Mass., 1940.
Milburn, K., and Barlow, E. W. "Ocean currents". Mar. Observ., **19**, 146, pp. 225—32, London, 1949.

Mosby, H. "Experiments on bottom friction". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, p. 133, Bergen, 1949.
Putnam, J. A., Munk, W. H., and Traylor, M. A. "The prediction of longshore currents". Trans. American Geophys. Union, **30**, 3, pp. 337—45, Washington, 1949.
Stommel, H. "The westward intensification of wind-driven ocean currents". Trans. American Geophys. Union, **29**, 2, pp. 202—6, Washington, 1948. (Contrib. No. 408 Woods Hole Oceanogr. Inst.).
Sverdrup, H. U. "The wind and the sea". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 37—55, Bergen, 1949.

2) i Tides and Sea Level.

Barber, N. F. "Recent studies of waves and swell". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 135—6, Bergen, 1949.
Barber, N. F. "A diffraction analysis of a photograph of the sea". Nature, **164**, 4168, p. 485, London, 1949.
Barnaby, C. F. "Effect of rain in calming the sea". Nature, **164**, 4179, p. 968, London, 1949.
Blue, F. L., and Johnson, J. W. "Diffraction of water waves passing through a breakwater gap". Trans. American Geophys. Union, **30**, 5, pp. 705—18, Washington, 1949.
Darbyshire, J. "The correlation between microseisms and sea-waves". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 19—20, Bergen, 1949.
Deacon, G. E. R. "The growth and decay of waves". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 82—3, Bergen, 1949.
Deacon, G. E. R. "Waves and swell". Quart. Journ., Roy. Meteorol. Soc., **75**, 325, pp. 227—38, London, 1949.
Deacon, G. E. R. "Storm warnings from waves and microseisms". Weather, **4**, pp. 74—9, London, 1949.
Deevey, E. S. "On the date of the last rise of sea level in southern New England". American Journ. Sci., **246**, pp. 329—52, New Haven, Conn., 1948.
Donn, W. L. "Studies of waves and swell in the western North Atlantic". Trans. American Geophys. Union, **30**, 4, pp. 507—16, Washington, 1949.
Doodson, A. T. "Storm surges in the North Sea". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, p. 148, Bergen, 1949.
Egedal, J. "On the reliability of the derived values of mean sea-level". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 119—20, Bergen, 1949.
Folsom, R. G. "Measurement of ocean waves". Trans. American Geophys. Union, **30**, 5, pp. 691—9, Washington, 1949.
Francis, J. R. D. "Laboratory experiments on wind-generated waves". Journ. Mar. Res., **8**, 2, pp. 120—31, New Haven, Conn., 1949.
Groen, P. "Note on the properties of internal waves". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 137—8, Bergen, 1949.
Hansen, W. "The computation of the tides in ocean areas of any shape by means of the method of boundary values". Deutsch. Hydrogr. Zeitschr., **1**, pp. 157—63, Hamburg, 1948.
Haurwitz, B. "Ocean surface waves". Ann. New York Acad. Sci., **51**, 3, New York, 1949.
Isaacs, J. D., and Wiegel, R. L. "The measurement of wave heights by means of a float in an open-end pipe". Trans. American Geophys. Union, **30**, 4, pp. 501—6, Washington, 1949.
Keller, J. B. "The solitary wave and periodic waves in shallow water". Comm. Appl. Math., **1**, pp. 323—39, ?, 1948.
Lacombe, H. "Note sur la Marée de la Manche Centrale". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 127—9, Bergen, 1949.
Longuet-Higgins, M. S. "The generation of microseisms by sea-waves". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 17—18, Bergen, 1949.
Lundbak, A. "Some peculiar tidal variations". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 125—6, Bergen, 1949.
Meaney, C. D. "Mean sea-level as a geophysical datum". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 121—4, Bergen, 1949.
Munk, W. H. "Spectrum of gravity waves in the sea". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, p. 134, Bergen, 1949.

Proudman, J. "The applicability of Laplace's differential equations of the tides". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 84—5, Bergen, 1949.
Putnam, J. A. "Loss of wave energy due to percolation in a permeable sea bottom" Trans. American Geophys. Union, **30**, 3, pp. 349—56, Washington, 1949.
Scholte, J. G. "Over het verband tussen zeegolven en microseismen". Nederlandsche Acad. van Wetensch., Afdeel. Natuurk., **52**, pp. 669—83, Amsterdam, 1943.
Seiwell, H. R. "Evaluation of sea-surface roughness from underwater-pressure recordings". Trans. American Geophys. Union, **29**, 2, pp. 197—201, Washington, 1948.
Seiwell, H. R., and Wadsworth, G. P. "A new development in ocean-wave research". Science, **109**, pp. 271—4, New York, 1949.
Thijsse, J. T. "Dimensions of wind-generated waves". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, pp. 80—1, Bergen, 1949.
Tomczak, G. "Zur Frage des Luftdruckeinflusses auf den Wasserstand". Deutsch. Hydrogr. Zeitschr., **2**, 4, pp. 130—3, Hamburg, 1949.
Unna, P. J. H. "Speed of wave energy". Nature, **164**, 4177, pp. 887—8, London, 1949.
Wiegel, R. L. "An analysis of data from wave recorders on the Pacific coast of the United States". Trans. American Geophys. Union, **30**, 5, pp. 700—4, Washington, 1949.
Zerbe, W. B. "The tide in the David Taylor Model Basin". Trans. American Geophys. Union, **30**, 3, pp. 357—68, Washington, 1949.

2) j Geography, Geology and Bottom Deposits.

Daly, R. A. "Coral reefs — a review". American Journ. Sci., **246**, pp. 193—207, New Haven, Conn., 1948.
Nares, J. D. "Limits of oceans and seas". Assoc. d'Océanogr. Phys., Union Géodés. et Géophys. Internat., Proc.-Verb. 4, p. 78, Bergen, 1949.
Pettersson, H. "Exploring the bed of the ocean". Nature, **164**, 4168, pp. 468—70, London, 1949.
Pettersson, H. "The geochronology of the deep ocean bed". Tellus, **1**, pp. 1—5, Stockholm, 1949.
Stephenson, W. "Certain effects of agitation upon the release of phosphate from mud". Journ. Mar. Biol. Assoc. U. K., N. S., **28**, 2, pp. 371—80, Cambridge, 1949.
Stetson, H. C. "The sediments and stratigraphy of the east coast continental margin: Georges Bank to Norfolk Canyon". Pap. in Phys. Oceanogr. and Meteorol., **11**, 2, Cambridge and Woods Hole, Mass., 1949.
Wiseman, J. D. H. "Geology of the deep-sea floor". Nature, **164**, 4173, pp. 682—4, London, 1949.

2) k Ice.

Anon. "Arctic ice and its drift into the north Atlantic Ocean". Pilot chart of the north Atlantic Ocean, Edition 9, Supplement, Washington, 1949.

2) l Meteorology.

Anon. "Klimatologie des östlichen Teils des Mittelatlantischen Ozeans nach Schiffsbeobachtungen". Meteorol. Amt f. Nordwestdeutschland, Hamburg, 1947.
Legrand, J. "Sur le réchauffement du climat des côtes septentrionales de l'Europe entre 1866 et 1936 et au dela". Comptes Rendus, Acad. Sci., **212**, pp. 563—4, Paris, 1941.
Rodewald, M. "Klima und Wetter des Fischereigebiets Bäreninsel". Meteorol. Amt f. Nordwestdeutschland, Hamburg, 1949.
Roll, H. U. "Vergleichende Betrachtung und Kritik von Windprofilmessungen auf See". Ann. Meteorol., 2 Jahrg., 3—4, pp. 71—8, Hamburg, 1949.
Woodcock, A. H., and Gifford, M. M. "Sampling atmospheric sea-salt nuclei over the ocean". Journ. Mar. Res., **8**, 2, pp. 177—97, New Haven, Conn., 1949.

3) Plankton.

3) a Apparatus and Methods.

Barnes, H. "A statistical study of the variation in vertical plankton hauls with special reference to the loss of the catch with divided hauls". Journ. Mar. Biol. Assoc. U. K., N. S., **28**, 2, pp. 429—46, Cambridge, 1949.
Cole, H. A., and Knight-Jones, E. W. "Quantitative estimation of marine nannoplankton". Nature, **164**, 4173, pp. 694—6, London, 1949.

Rodhe, W. "Zur Verbesserung der quantitativen Planktonmethodik nebst Profilen des Crustaceenplanktons aus drei smaländischen Seen". Zool. Bidrag fr. Uppsala, **20**, pp. 465—77, Uppsala and Stockholm, 1941.

3) b General.

Lucas, C. E. "Notes on continuous plankton records at 10 m. depth in the North Sea and north-eastern Atlantic during 1946—1947". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 63—6, Copenhague, 1949.
Riley, G. A. "Quantitative ecology of the plankton of the western North Atlantic". Bull. Bingham Oceanogr. Collect., **12**, 3, New Haven, Conn., 1949.

3) c Phytoplankton.

Boden, B. P. "The diatoms collected by the U. S. S. 'Cacopan' in the Antarctic in 1947". Journ. Mar. Res., **8**, 1, pp. 6—13, New Haven, Conn., 1949.
Hustedt, F. "Die Struktur der Diatomeen und die Bedeutung des Elektronenmikroskops für ihre Analyse". Arch. f. Hydrobiol., **41**, pp. 315—32, Stuttgart, 1945.
Pratt, D. M. "Experiments in the fertilization of a salt water pond". Journ. Mar. Res., **8**, 1, pp. 36—59, New Haven, Conn., 1949.
Riley, G. A., and Arx, R. von. "Theoretical analysis of seasonal changes in the phytoplankton of Husan Harbor, Korea". Journ. Mar. Res., **8**, 1, pp. 60—72, New Haven, Conn., 1949.
Silva, E. de S. E., and Santos-Pinto, J. D. "O plancton de Baia de S. Martinho de Porto I. Diatomáceas e Dinoflagelados". Bol. Soc. Portuguesa Ciencias Natur., **16**, 2, pp. 134—87, Lisboa, 1948.
Subrahmanyan, R. "On somatic division, reduction division, auxospore-formation and sex differentiation in *Navicula halophila* (Grunov) Cleve". Curr. Sci., **14**, pp. 75—7, Bangalore, 1945.
Subrahmanyan, R. "On the formation of auxospores in *Bacteriastrum*". Curr. Sci., **14**, pp. 154—5, Bangalore, 1945.
Subrahmanyan, R. "On the cell-division and mitosis in some south Indian diatoms". Proc. Indian Acad. Sci., **22**, pp. 331—54, Bangalore, 1945.
Subrahmanyan, R. "On the occurrence of microspores in some centric diatoms of the Madras coast". Journ. Indian Bot. Soc., **25**, pp. 61—6, Madras, 1949.

3) d Zooplankton.

Banner, A. H. "A taxonomic study of the Mysidacea and Euphausiacea (Crustacea) of the north-eastern Pacific". Trans. Roy. Canadian Inst., **26**, pp. 345—99, Toronto, 1948?.
Bigelow, H. B., and Sears, M. "Siphonophorae". Rep. Danish Oceanogr. Exped. 1908—10 to the Mediterranean and adjacent seas, **2**, H, 2, pp. 1—144, Copenhagen, 1939.
Cattley, J. G., and Harding, J. P. "*Penilia*, a Cladoceran normally found off tropical and subtropical coasts, recorded in North Sea plankton". Nature, **164**, 4162, pp. 238—9, London, 1949.
Davis, C. C. "The pelagic Copepoda of the north-eastern Pacific Ocean". Univ. of Washington, Publ. in Biol., **14**, pp. 1—118, Seattle, 1949.
Elofson, O. "Zur Kenntnis der marinen Ostracoden Schwedens mit besonderer Berücksichtigung des Skageraks". Zool. Bidrag fr. Uppsala, **19**, pp. 215—534, Uppsala and Stockholm, 1941.
Forsman, B. "Untersuchungen über die Cumaceen des Skageraks". Zool. Bidrag fr. Uppsala, **18**, pp. 1—162, Uppsala and Stockholm, 1938.
Fraser, J. H. "Plankton of the Faroe-Shetland Channel and the Faroes, June and August 1947". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 27—8, Copenhague, 1949.
Fraser, J. H. "The distribution of Thaliacea (salps and doliolids) in Scottish waters, 1920 to 1939". Scottish Home Dept., Fish. Div., Sci. Invest. 1949, 1, Edinburgh, 1949.
Fraser, J. H. "The occurrence of unusual species of Chaetognatha in Scottish plankton collections". Journ. Mar. Biol. Assoc. U. K., N. S., **28**, 2, pp. 489—91, Cambridge, 1949.
Hult, J. "Über einige für die Westküste Schwedens neue Evertebraten". Zool. Bidrag fr. Uppsala, **20**, pp. 455—60, Uppsala and Stockholm, 1941.
Jagersten, G. "Zur Kenntnis der Physiologie der Zeugung bei *Sagitta*". Zool. Bidrag fr. Uppsala, **18**, pp. 397—413, Uppsala and Stockholm, 1940.
Jespersen, P., and Russell, F. S. (Editors) "Fiches d'identification du zooplankton". 1—17, Cons. Perm. Internat. Explor. Mer, Copenhague, 1949.

Mistakidis, M. "A new variety of *Tigriopus lilljeborgii*, Norman". Dove Mar. Lab. Rep., Cullercoats, Ser. 3, 10, pp. 55—70, Newcastle-upon-Tyne, 1949.
Nyholm, K. G. "Zur Entwicklung und Entwicklungsbiologie der Ceriantharien und Aktinien". Zool. Bidrag fr. Uppsala, **22**, pp. 87—248, Uppsala and Stockholm, 1943.
Rees, C. B. "Continuous plankton records: the distribution of *Calanus finmarchicus* (Gunn.) and its two forms in the North Sea, 1938—39". Hull Bull. Mar. Ecol., **2**, 14, pp. 215—75, Hull, 1949.
Rees, C. B., and Cattley, J. G. "*Processa aequimana* Paulson in the North Sea". Nature, **164**, 4165, p. 367, London, 1949.
Ruud, J. T. "Euphausiacea". Rep. Danish Oceanogr. Exped. 1908—10 to the Mediterranean and adjacent seas, **2**, D, 6, pp. 1—86, Copenhagen, 1936.
Stommel, H. "Trajectories of small bodies sinking slowly through convection cells". Journ. Mar. Res., **8**, 1, pp. 24—9, New Haven, Conn., 1949.
Tesch, J. J. "Heteropoda". Carlsberg Found. Oceanogr. Exped. round the world 1928—30, Dana-Report **34**, Copenhagen and London, 1949.
Wesenberg-Lund, E. "Pelagic Polychaetes of the families Aphroditidae, Phyllodocidae, Typhloscolecidae and Alciopidae". Rep. Danish Oceanogr. Exped. 1908—10 to the Mediterranean and adjacent seas, **2**, E, 1, pp. 1—45, Copenhagen, 1939.

4) Organic Production.

4) a General.

Buch, K., och Halme, E. "Produktionen i östersjön". Terra, 1, Helsinki, 1947.
Kalle, K. "Fluoreszenz und Gelbstoff im Bottnischen und Finnischen Meerbusen". Deutsch. Hydrogr. Zeitschr., **2**, 4, pp. 117—24, Hamburg, 1949.
Maucha, R. "Einige Gedanken zur Frage des Nährstoffhaushalts der Gewässer". Hydrobiologia, **1**, 3, pp. 225—37, den Haag, 1949.
Pratt, D. M. "Experiments in the fertilization of a salt water pond". Journ. Mar. Res., **8**, 1, pp. 36—59, New Haven, Conn., 1949.

5) Bottom Fauna and Flora.

5) a Apparatus and Methods.

Enequist, P. "Ein neuer Zerteiler — Bodenstecher für Sedimentanalyse zu ökologischen Zwecken". Zool. Bidrag fr. Uppsala, **20**, pp. 461—4, Uppsala and Stockholm, 1941.
Holme, N. A. "A new bottom-sampler". Journ. Mar. Biol. Assoc. U. K., N. S., **28**, 2, pp. 323—32, Cambridge, 1949.

5) b Systematics and Development.

Berg, S. E. "Die Entwicklung und Koloniebildung bei *Funiculina quadrangularis* (Pallas)". Zool. Bidrag fr. Uppsala, **20**, pp. 1—100, Uppsala and Stockholm, 1941.
Berrill, N. J. "The polymorphic transformations of *Obelia*". Quart. Journ. Microscop. Sci., Ser. 3, **90**, 3, pp. 235—64, Oxford and London, 1949.
Das, S. M. "British Folliculinidae (Ciliata, Heterotricha)". Journ. Mar. Biol. Assoc. U. K., N. S., **28**, 2, pp. 381—93, Cambridge, 1949.
Dieuzeide, R. "Contribution à l'étude de deux types de Gastéropodes Pulmones Marins. *Siphonaria algesirae* Quoy et Gaimard, *Gadinia garnoti* Payraudeau". Stat. d'Aquicul. et de Pêche de Castiglione, Fasc. 1 & 2, Alger, 1935.
Einarsson, H. "Echinoderma". Zool. of Iceland, **4**, 70, Copenhagen and Reykjavik, 1948.
Hanson, J. "Observations on the branchial crown of the Serpulidae (Annelida, Polychaeta)". Quart. Journ. Microscop. Sci., Ser. 3, **90**, 3, pp. 221—33, Oxford and London, 1949.
Johansson, K. E. "*Lamellisabella zachsi* Uschakow, ein Vertreter einer neuen Tierklasse, Pogonophora". Zool. Bidrag fr. Uppsala, **18**, pp. 253—68, Uppsala and Stockholm, 1939.
Johansson, J. "Anatomische Studien über die Gastropodenfamilien Rissoidae und Littorinidae". Zool. Bidrag fr. Uppsala, **18**, pp. 287—396, Uppsala and Stockholm, 1939.
Knight-Jones, E. W., and Waugh, G. D. "On the larval development of *Elminius modestus* Darwin". Journ. Mar. Biol. Assoc. U. K., N. S., **28**, 2, pp. 413—28, Cambridge, 1949.

Lemche, H. "Northern and arctic tectibranch Gastropods. 1. The larval shells. 2. A revision of the Cephalaspid species". Kgl. Danske Vidensk. Selsk., Biol. Skr., **5**, 3, København, 1949.
Lindroth, A. "Echiurida, Sipunculida und Enteropneusta aus dem Skagerak 1933". Zool. Bidrag fr. Uppsala, **20**, pp. 443—53, Uppsala and Stockholm, 1941.
Nyholm, K. G. "Zur Entwicklung und Entwicklungsbiologie der Ceriantharien und Aktinien". Zool. Bidrag fr. Uppsala, **22**, pp. 87—248, Uppsala and Stockholm, 1943.
Pickford, G. E. "The *Octopus bimaculatus* problem: a study in sibling species". Bull. Bingham Oceanogr. Collect., **12**, 4, New Haven, Conn., 1949.
Russell, F. S. "On the hydroid of *Eutima gracilis* (Forbes and Goodsir)". Journ. Mar. Biol. Assoc. U. K., N. S., **28**, 2, pp. 479—80, Cambridge, 1949.
Silén, L. "Origin and development of the cheilo-ctenostomatous stem of Bryozoa". Zool. Bidrag fr. Uppsala, **22**, pp. 1—59, Uppsala and Stockholm, 1942.
Silén, L. "On the formation of the interzoidal communications of the Bryozoa". Zool. Bidrag fr. Uppsala, **22**, pp. 433—88, Uppsala and Stockholm, 1944.
Thomas, J. G. "*Pomatoceros*, *Sabella* and *Amphitrite*". Mem. Liverpool Mar. Biol. Com., 33, Liverpool, 1940.
Wesenberg-Lund, E. "Maldanidae (Polychaeta) from west Greenland waters". Medd. om Grønland, **134**, 9, Copenhagen, 1948.

5) c Distribution and Ecology.

Danois, E. le. "Les profondeurs de la mer". Payot, Paris, 1948.
Purchon, R. D., and Jefferson, G. T. "A hemichordate from west Wales". Nature, **164**, 4177, pp. 881—2, London, 1949.
Pyefinch, K. A. "Short-period fluctuations in the numbers of barnacle larvae, with notes on comparisons between pump and net plankton hauls". Journ. Mar. Biol. Assoc. U. K., N. S., **28**, 2, pp. 353—69, Cambridge, 1949.
Remane, A. "Einführung in die zoologische Ökologie der Nord- und Ostsee". Tierwelt d. Nord- u. Ostsee (Grimpe u. Wagler), **34**, 1 a, Leipzig, 1940.
Rzoska, J. "*Cordylophora* from the upper White Nile". Ann. and Mag. Natur. Hist., Ser. 12, **2**, 19, pp. 558—60, London, 1949.
Verwey, J. "Habitat selection in marine animals". Folia Biotheoretica, 4, pp. 1—22, Leiden, 1949.
Wallace, M. M., Pertuit, C. J., and Hvatum, A. R. "Contribution to the biology of the King Crab (*Paralithodes camtschatica* Tilesius)". U. S. Dept. Int., Fish and Wildlife Serv., Fish. Leaflet 340, Washington, 1949.
Yonge, C. M. "On the structure and adaptations of the Tellinacea, deposit-feeding Eulamellibranchia". Phil. Trans. Roy. Soc. London, **234**, 609, London, 1949.

5) d Physiology and Behaviour.

Bauchau, A. "Growth and sinus glands in a crab". Nature, **164**, 4171, pp. 615—6, London, 1949.
Denzer, H. W. "Untersuchungen über die Körpertemperatur der Regenbogenforelle". Arch. f. Fisch. Wiss., 1 Jahrg., 3—4, pp. 101—12, Hamburg, 1948.
Graham, A. "The molluscan stomach". Trans. Roy. Soc. Edinburgh, **61**, 3, pp. 737—8, Edinburgh, 1949.
Heldt, J. H. "Observations sur une ponte d'*Octopus vulgaris* Lmk.". Bull. Soc. Sci. Natur. de Tunisie, **1**, 2, pp. 87—90, Tunis, 1948.
Humphrey, G. F. "The adenoisinetriphosphatase activity of myosins from marine animals". Physiol., Comparata et Oecologia, **1**, 2, pp. 89—94, den Haag, 1949.
Hunter, W. R. "The structure and behaviour of *Hiatella gallincana* (Lamarck) and *H. arctica* (L.), with special reference to the boring habit". Proc. Roy. Soc. Edinburgh, B, **63**, 3, pp. 271—89, Edinburgh, 1949.
Ino, T. "The effect of food on growth and coloration of the topshell (*Turbo cornatus* Solander)". Journ. Mar. Res., **8**, 1, pp. 1—5, New Haven, Conn., 1949.
Jørgensen, C. B. "The rate of feeding by *Mytilus* in different kinds of suspension". Journ. Mar. Biol. Assoc. U. K., N. S., **28**, 2, pp. 333—44, Cambridge, 1949.
Kirtisinghe, P. "Unicellular algae in association with invertebrates". Nature, **164**, 4179, p. 970, London, 1949.
Renaud, L. "Le cycle des réserves organiques chez les crustacés décapodes". Ann. Inst. Océanogr. Monaco, **24**, 3, Paris, 1949.
Richards, J. R. "A new method of ciliary feeding in the brachiopod *Neothyris lenticularis*". Nature, **164**, 4165, pp. 367—8, London, 1949.
Robertson, J. D. "Ionic regulation in some marine vertebrates". Journ. Exper. Biol., **26**, 2, pp. 182—200, Cambridge, 1949.

Rodenhouse, L. Z., and Buberlet, J. E. "The morphology and behaviour of the cushion star *Pteraster tesselatus* Ives". Univ. of Washington, Publ. in Biol., **12**. 3, pp. 21—48, Seattle, 1946.

Rothschild, L., and Swann, M. M. "The fertilization reaction in the sea-urchin egg. A propagated response to sperm attachment". Journ. Exper. Biol., **26**. 2, pp. 164—76, Cambridge, 1949.

Rothschild, L. "The fertilization reaction in the sea-urchin egg. A note on diffusion considerations". Journ. Exper. Biol., **26**. 2, pp. 177—81, Cambridge, 1949.

Sylvest, O. "Copulation observed in *Viviparus fasciatus* (O. F. Müller)". Hydrobiologia, **1**. 3, pp. 309—11, den Haag, 1949.

Wells, G. P. "Respiratory movements of *Arenicola marina* L. intermittent irrigation of the tube, and intermittent aerial respiration". Journ. Mar. Biol. Assoc. U. K., N. S., **28**. 2, pp. 447—64, Cambridge, 1949.

Wells, G. P. "The behaviour of *Arenicola marina* L. in sand, and the role of spontaneous activity cycles". Journ. Mar. Biol. Assoc. U. K., N. S., **28**. 2, pp. 465—78, Cambridge, 1949.

5) e Parasitic Forms.

Fretter, V., and Graham, A. "The structure and mode of life of the Pyramidellidae, parasitic opisthobranchs". Journ. Mar. Biol. Assoc. U. K., N. S., **28**. 2, pp. 493—532, Cambridge, 1949.

5) f Marine Plants.

Lund, S. "Immigration of algae into Danish waters". Nature, **164**, 4171, p. 616, London, 1949.

Marshall, S. M., Newton, L., and Orr, A. P. "A study of certain British seaweeds and their utilization in the preparation of agar". H. M. S. O., London, 1949.

Nasr, A. H., and Aleem, A. A. "Ecological studies of some marine algae from Alexandria". Hydrobiologia, **1**. 3, pp. 251—81, den Haag, 1949.

Newton, L. "The utilization of the macroscopic marine algae through the ages". Advancement of Sci., **6**, 23, pp. 275—85, London, 1949.

Sandholzer, L. A., Dean, M. E., Arcisz, W., and Bradley, M. C. "Studies of bacteriological agar. 2. Bacteriological studies". U. S. Dept. Int., Fish and Wildlife Serv., Fish. Leaflet, 335, pp. 25—41, Washington, 1949.

Stoloff, L. S., and Lee, C. R. "Studies of bacteriological agar. 1. Physical and chemical properties". U. S. Dept. of Int., Fish and Wildlife Serv., Fish. Leaflet, 335, pp. 3—25, Washington, 1949.

Wilson, D. P. "The decline of *Zostera marina* L. at Salcombe and its effect on the shore". Journ. Mar. Biol. Assoc. U. K., N. S., **28**. 2, pp. 395—412, Cambridge, 1949.

6) Fish.

6) a Systematics, Morphology and Development.

Al-Hussaini, A. H. "On the functional morphology of the alimentary tract of some fish in relation to differences in their feeding habits: anatomy and histology". Quart. Journ. Microscop. Sci., **90**. 2, pp. 109—39, London and Oxford, 1949.

Chabanaud, P. "Revision des Cynoglossidae (s. str.) de l'Atlantique oriental". Bull. Mus. Nation. Hist. Natur., 2e Sér., **21**, 1, pp. 60—6, Paris, 1949.

Chabanaud, P. "Revision des Cynoglossidae (s. str.) de l'Atlantique oriental (suite)". Bull. Mus. Nation. Hist. Natur., 2e Sér., **21**. 2, pp. 202—9, Paris, 1949.

Chaux, J., and Fang, P. W. "Catalogue des Siluroidei d'Indochine de la collection du Laboratoire des Pêches coloniales au Muséum, avec la description de six espèces nouvelles". Bull. Mus. Nation. Hist. Natur., 2e Sér., **21**. 2, pp. 194—201, Paris, 1949.

Fraser-Brunner, A. "Note on the electric rays of the genus *Torpedo*". Ann. and Mag. Natur. Hist., 12 Ser., **2**. 24, pp. 943—7, London, 1949.

Templeman, W. "The life history of the caplin (*Mallotus villosus* O. F. Müller) in Newfoundland waters". Bull. Newfoundland Government Lab., Res. Bull., 16, St. John's, 1945.

6) b Distribution and Fluctuations.

Aurich, H. J. "Die Verbreitung der pelagischen Fischbrut in der südlichen Nordsee während der Frühjahrsfahrten 1926—1937 der deutschen Forschungsschiffe 'Poseidon' und 'Makrele'". Helgoland Wiss. Meeresunters., **2**. 2, pp. 183—225, Helgoland, 1940.

Barnard, K. H. "Occurrence of the spiny dog-fish *Oxynotus centrina* in south African waters". Nature, **164**, 4179, p. 970, London, 1949.

Danois, E. le. "Les profondeurs de la mer". Payot, Paris, 1948.
Hart, J. L. "Increased abundance of an unusual British Columbia fish, the California pompano". Canadian Field-Naturalist, **63**, 3, pp. 101—2, Ottawa, 1949.
Meyer, P.-F. "Gastfische in der Ostsee". Deutsche Fischwirtsch., 11 Jahrg., 13, Berlin, 1944.
Monod, T. "Données statistiques et biologiques sur quelques poissons du Niger moyen". Cybium, 4, pp. 4—61, Paris, 1949.
Tucker, D., and Palmer, G. "New British records of two rare deep-sea fishes: *Oxynotus paradoxus* Frade and *Aphanopus carbo* Lowe". Nature, **164**, 4178, pp. 930—1, London, 1949.

6) c Physiology and Behaviour.

Anon. "Time of activity of freshwater fish spermatozoa in relation to temperature". Zool. Bidrag fr. Uppsala, **25**, pp. 165—8, Uppsala and Stockholm, 1947.
Bérzins, B. "Über temperaturbedingte Tierwanderungen in der Ostsee". Oikos, **1**, 1, pp. 30—3, ?, 1949.
Haempel, O. "Geschlechtsdifferenzierung bei Fischen". Arch. f. Fisch. Wiss., 1 Jahrg., 1—2, pp. 9—12, Hamburg, 1948.
Humpherey, G. F. "The adenoisinetriphosphatase activity of myosins from marine animals". Physiol., Comparata et Oecologia, **1**, 2, pp. 89—94, Den Haag, 1949.
Phillips, A. M. "The Vitamin B requirement of trout". Trans. American Fish. Soc., **76**, pp. 34—45, New York, 1948.
Verwey, J. "Migration in birds and fishes". Bijdragen tot de Dierkunde, **28**, pp. 477—504, Leiden, 1949.

6) d Parasites and Diseases.

Brian, A. "Sur trois Copepodes parasites de poissons des Côtes Algériennes. (*Diocus clini* n. var. *Dieuzeidei* Brian: *Perissopus communis* Rathbun; *Pandarus bicolor* Leach)". Stat. d'Aquicul. Pêche de Castiglione, N. S., 1, pp. 9—18, Alger, 1940.
Crofton, H. D. "The parasites of some littoral fishes of Northumberland". Dove Mar. Lab. Rep. Cullercoats, Ser. 3., 9, pp. 59—64, Newcastle-upon-Tyne, 1947.
Kuitunen-Ekbaum, E. "The occurrence of *Sarcotaces* in Canada". Journ. Fish. Res. Board Canada, **7**, 9, pp. 505—12, Toronto, 1947.
Stekhoven, J. H. S., and Punt, A. "Nematoda parasitica". Tierwelt d. Nord- u. Ostsee (Grimpe u. Wagler), **35**, 5c, Leipzig, 1944.

7) Marine Fisheries.

7) a Commercial Fisheries: Statistical.

Anon. "Fishery statistics of the United States, 1944". U. S. Dept. Int., Fish and Wildlife Serv., Statist. Digest, 16, Washington, 1948.
Anon. "Statistiques des régions de pêches, (année 1944, 2me semestre), (année 1945), (année 1946)". Rev. Trav. Office des Pêches Marit., **14**, 1—4, pp. 161—81, Paris, 1948.
Anon. "Report on the Fisheries of Scotland 1939—1948". Scottish Home Dept., Edinburgh, 1949.
Anon. "Fourteenth annual report for the year ended 31st March, 1949". Herring Industry Board, London, 1949.
Anon. "Die Seefischerei des Vereinigten Wirtschaftsgebietes im Jahre 1948". Frankfurt, 1949.
Anon. "Sea fisheries statistical tables 1948". H. M. S. O., London, 1949.
Anon. "Notes on the improvement of European fisheries statistics". Food and Agric. Organization of the United Nations, Lake Success, 1949.
Rosén, N. (Editor). "Bulletin statistique des pêches maritimes, (**30**, 1940—44)". Cons. Perm. Internat. Explor. Mer. Copenhague, 1949.

7) b Fish Technology.

Anon. "Report of the Food Investigation Board with the report of the Director of food investigation for the year 1947". Dept. Sci. and Indust. Res., London, 1949.
Castell, C. H. "Nitrite-reducing bacteria on cod fillets". Journ. Fish. Res. Board Canada, **7**, 9, pp. 528—35, Toronto, 1949.
Castell, C. H. "Spoilage rates at 37° and 32°F". Progress Rep. Atlantic Biol. Stat., 46, pp. 3—6, St. Andrews, N. B., 1949.
Cutting, C. L. "Notes on experiments of smoking eels". Food Invest. Board, Torry Res. Stat., Rec. Mem., 66, Aberdeen, 1949.

Deas, C. P., and Tarr, H. L. A. "Amino acid composition of fishery products". Journ. Fish. Res. Board Canada, **7**, 9, pp. 513—21, Toronto, 1949.
Dreosti, G. M., and Southall, C. L. "Preparation of crawfish offal for subsequent drying". Fish. Indust. Res. Inst., Progress Rep. No. 4, Cape Town, 1949.
Dyer, W. J., and Castell, C. H. "Further studies on the bacteriological reduction of nitrite in fish during spoilage". Journ. Fish. Res. Board Canada, **7**, 9, pp. 536—44, Toronto, 1949.
Gerhardsen, G. M., and Gertenbach, L. P. D. "Salted cod and related species". Food and Agric. Organisation, Fish. Study 1, Washington, 1949.
Junker, M. "Über die Änderungen im Vitamin-A-Gehalt von Heringen während des Konservierungsprozesses". Arch. f. Fisch. Wiss., 1 Jahrg., 1—2, pp. 13—21, Hamburg, 1948.
Lovern, J. A. "The fishery industries of north America. Part 3, Canning". Food Manufacture, **23**, pp. 257—62, London, 1949.
Lovern, J. A. "The fishery industries of north America. Part 4, Fish meal and oil". Food Manufacture, **23**, pp. 323—7, London, 1949.
Lovern, J. A. "Fish oils". Journ. Oil and Colour Chemists' Assoc., **32**, 345, pp. 113—22, Slough, 1949.
Meyer, P.-F. "Qualitätsuntersuchungen an Nutzfischen der Ostsee". Zeitschr. f. Fisch., **41**, 1, pp. 47—67, Berlin, 1943.
Shewan, J. M. "Some bacteriological aspects of handling, processing and distribution of fish". Journ. Roy. Sanitary Inst., 69, pp. 394—421, London, 1943.
Syme, J. D. "Fish and fish inspection". H. K. Lewis and Co. Ltd., London, 1949.
Tarr, H. L. A., and Cooke, N. E. "Control of rancidity in fish flesh. 3. Carbonyl enediols as anti-oxidants". Journ. Fish. Res. Board Canada, **7**, 9, pp. 522—7, Toronto, 1949.
Tarr, H. L. A., and Deas, C. P. "Bacteriological peptones from fish flesh". Journ. Fish. Res. Board Canada, **7**, 9, pp. 552—60, Toronto, 1949.

7) c Fishing Vessels and Gear.

Anon. "First trawler with Doxford machinery". The Motor Ship, **30**, 358, pp. 290—2, London, 1949.
Brandt, A. von. "Arbeitsmethoden der Netzforschung". Schriftenr. d. Reichsanst. f. Fisch., **2**, Stuttgart, 1947.
Bandt, A. von. "Netzweichheit und Netzhärte. Ein Beitrag zum Begriff der Fangigkeit bei Kiemennetzen". Arch. f. Fisch. Wiss., 1 Jahrg., 3—4, pp. 173—81, Hamburg, 1948.
Farrar, B. "Studies on the preservation of fish nets". British Columbia Res. Council, Technical Bull., 11, Vancouver, B. C., 1949.
Hodgson, A. "Introduction to trawling". A. Hodgson, Grimsby, 1949.
Klust, G. "Schleppnetzgarne aus Manila, Weichhanf und Perlon". Arch. f. Fisch. Wiss., 1 Jahrg., 1—2, pp. 78—92, Hamburg, 1948.
Meyer, P.-F., und Rübenberg, L. "Die Ankerreuse". Zeitschr. f. Fisch., **40**, 3, pp. 303—28, Neudamm u. Berlin, 1942.
Meyer, P.-F. "Die Bodensee-Ankerreuse (Trappnetz)". Zeitschr. f. Fisch., **43**, pp. 262—71, Berlin, 1943.

8) Marine Fishery Investigations.

8) a Stocks and Effects of Fishing.

Boerema, L. K., and Cox-Heikens, M. C. "The Dutch fishery for demersal sea fish in 1947". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 95—100, Copenhague, 1949.
Bückmann, A. "Die Fischerei der Finkenwerder und Schulauer Hochseekutter im Sommer — Herbst 1945". Arch. f. Fisch. Wiss., 1 Jahrg., 1—2, pp. 36—63, Hamburg, 1948.
Holt, S. J. "The fishing intensity on the plaice stock of the southern North Sea". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, p. 111, Copenhague, 1949.
Jensen, A. J. C. "The stocks of plaice in the North Sea and the transition area during the war". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp. 19—25, Copenhague, 1948.
Letaconnoux, R. "Effets de la guerre sur la constitution des stocks de poissons". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp. 52—62, Copenhague, 1948.

Margetts, A. R., and Holt, S. J. "The effect of the 1939—1945 war on the English North Sea trawl fisheries". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp. 26—46, Copenhague, 1948.
Meyer, P.-F. "Raubbau im Meer". Die blauen Fischbändchen, 9, Hamburg, 1947.
Molander, A. R. "The Swedish witch fishery in the Skagerak and the North Sea". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp. 9—12, Copenhague, 1948.
Molander, A. R. "The Swedish ling fishery before and since the war". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp. 13—4, Copenhague, 1948.
Mulicki, Z. "Changes in the composition of the flounder stock in the Gulf of Gdansk during the war". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp. 15—8, Copenhague, 1948.
Parrish, B. B. "The haddock stocks in the North Sea during the second half of 1945". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp. 47—54, Copenhague, 1948.
Rollefsen, G. "The Arcto-Norwegian stock of cod". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp. 7—8, Copenhague, 1948.
Stephen, A. C. "Preliminary note on the immigration of certain marine species in Scottish waters. 1913 to 1947". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 83—6, Copenhague, 1949.
Various. "North-western area committee report of the sub-committee on Faxa Bay". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **120**, Copenhague, 1948.
Wallace, D. A. "Methods of fish management in the middle Atlantic states". Proc. Gulf and Caribbean Fish. Inst., Inaugural Session Miami Beach, August, 1948, pp. 60—4, Coral Gables, Florida, 1949.

8) b Cod.

Bückmann, A., und Ulbricht-Stier, A. "Die wichtigsten Ergebnisse der Kabeljauuntersuchungen der Biologischen Anstalt im Seegebiet von Helgoland". Ber. Deutsch. wiss. Kommission f. Meeresf. N. F., **11**, 4, pp. 406—28, Stuttgart, 1949.
Hessle, Chr. "Recent years' increase in the catches of cod in the Swedish fishery". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 145—8, Copenhague, 1949.
Rollefsen, G. "The Arcto-Norwegian stock of cod". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp. 7—8, Copenhague, 1948.

8) c Haddock.

Parrish, B. B. "Haddock. The stock in Faroese waters in 1947". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 30—1, Copenhague, 1949.
Parrish, B. B. "The haddock stocks in the North Sea during the second half of 1945". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp. 47—54. Copenhague, 1948.
Parrish, B. B. "Fish larvae, haddock". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 69—73, Copenhague, 1949.
Schuck, H. A. "Relationship of catch to changes in population size of New England haddock". Biometrics, **5**, 3, pp. 213—31, U. S. A., 1949.

8) e Other Gadoids.

Desbrosses, P. "Le merlan (*Gadus merlangus* Linné) de la côte française de l'Atlantique (Deuxième partie)". Rev. Trav. Office des Pêches Marit., **14**, 1—4, pp. 71—104, Paris, 1948.
Molander, A. R. "The Swedish ling fishery before and since the war". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp. 13—4, Copenhague, 1948.

8) f Plaice.

Holt, S. J. "The fishing intensity on the plaice stock of the southern North Sea". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, p. 111, Copenhague, 1949.
Jensen, A. J. C. "The stocks of plaice in the North Sea and the Transition Area during the war". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp. 19—25, Copenhague, 1948.
Jensen, A. J. C. "The Danish plaice fishery in the North Sea". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 101—2, Copenhague, 1949.
Margetts, A. R., and Holt, S. J. "The effect of the 1939—1945 war on the English North Sea trawl fisheries". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp.26—46, Copenhague, 1948.

Tåning, Å. V. "Preliminary results of marking experiments on plaice in the central North Sea 1946 and 1947". Cons. Perm. Internat. Explor. Mer. Ann. Biol., **4**. pp. 102—4, Copenhague, 1949.

Wimpenny, R. S. "The English plaice fishery in the southern North Sea and neighbouring waters in 1947". Cons. Perm. Internat. Explor. Mer. Ann. Biol., **4**. pp. 105—11, Copenhague, 1949.

8) g Sole.

Wimpenny, R. S. "The English steam trawler fishery for soles in 1947". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 112—4, Copenhague, 1949.

8) h Halibut.

Anon. "Regulation and investigation of the Pacific halibut fishery in 1948". Internat. Fish. Comm., Rep. 14, Seattle, Washington, 1949.

8) i Other Pleuronectidae.

Meyer, P.-F. "Untersuchungen über die Flundern in den Haffen, Bodden und Wieken der Ostsee". Zeitschr. f. Fisch., **39**, 1, pp. 1—57, Berlin u. Neudamm, 1941.

Molander, A. R. "The Swedish witch fishery in the Skagerak and the North Sea". Cons. Perm. Internat. Explor. Mer. Rapp. et Proc.-Verb., **122**. pp. 9—12, Copenhague, 1948.

Mulicki, Z. "Changes in the composition of the flounder stock in the Gulf of Gdansk during the war". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **122**, pp. 15—8, Copenhague, 1948.

Rae, B. B. "Lemon soles. Faroe 1947". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**. pp. 31—2, Copenhague, 1949.

8) j Herring.

Ancellin, J. "Statistiques biologiques et considérations sur les populations de harengs (*Clupea harengus* L.) de la Manche orientale et du sud de la Mer du Nord (Matériel prélevé en 1945—46)". Rev. Trav. Office des Pêches Marit., **14**. 1—4, pp. 25—32. Paris, 1948.

Ancellin, J. "Statistiques biologiques des populations de harengs de la Manche orientale et du sud de la Mer du Nord (1946—47)". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**. pp. 119—21, Copenhague, 1949.

Fridriksson, Á. "Herring. The Icelandic fishery in Faxa Bay in the years 1946—1948". Cons. Perm. Internat. Explor. Mer. Ann. Biol., **4**. pp. 38—44. Copenhague, 1949.

Gilis, C. "Observations biologiques sur les concentrations de harengs pleins du 'Fladen' et du 'Gut'". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 76—8, Copenhague, 1949.

Gilis, C. "Statistiques biologiques des concentrations annuelles de harengs suais sur la côte belge". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**. pp. 115—7, Copenhague, 1949.

Hodgson, W. C. "The East Anglian herring fishery in 1947". Cons. Perm. Internat. Explor. Mer. Ann. Biol., **4**. pp. 118—9, Copenhague, 1949.

Tester, A. L. "Populations of herring along the west coast of Vancouver Island on the basis of mean vertebral number, with a critique of the method". Journ. Fish. Res. Board Canada, **7**. 7, pp. 403—20, Toronto, 1949.

Veen, J. de, and Boerema, L. K. "The Dutch herring fisheries in 1947". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **4**, pp. 79—82, Copenhague, 1949.

8) k Sardine and other Clupeoids.

Dieuzeide, R. "Comment intensifier la pêche à la sardine et développer l'Industrie Sardinière sur nos côtes Algériennes". Stat. d'Aquicul. et Pêche de Castiglione, N. S., 1, pp. 59—77, Alger, 1940.

Furnestin, J. "Observations sur le sprat (*Clupea sprattus* Linné) des côtes méridionales de France (Atlantique et Méditerranée)". Rev. Trav. Office des Pêches Marit., **14**. 1—4, pp. 39—69, Paris, 1948.

Hildebrand, S. F. "A review of the American anchovies (family Engraulidae)". Bull. Bingham Oceanogr. Collect., **8**. 2, New Haven, Conn., 1943.

Letaconnoux, R. "Notes sur la sardine (*Clupea pilchardus* Walbaum) du Golfe de Gascogne". Rev. Trav. Office des Pêches Marit., **14**. 1—4, pp. 33—8, Paris, 1948.

8)l Tunny and Mackerel.

Bellon, L., and Bardan de Bellon, E. "Algunos datos sobre los 'Thunnidae' de Canarias". Bol. Inst. Español Oceanogr., 19, Madrid, 1949.

Fitch, J. E., and Flechsig, A. O. "A brief account of the Monterey Spanish mackerel, (*Scomberomorus concolor*)". California Fish and Game, **35**, 4, pp. 275—80, San Francisco, 1949.

Fraser-Brunner, A. "On the fishes of the genus *Euthynnus*". Ann. and Mag. Natur. Hist., Ser. 12, **2**, 20, pp. 622—7, London, 1949.

Roedel, P. M. "Movements of Pacific mackerel as demonstrated by tag recoveries". California Fish and Game, **35**, 4, pp. 281—91, San Francisco, 1949.

8)o Whales and Seals.

Colman, J. S. "The Newfoundland seal fishery and the second World War". Journ. Animal Ecology, **18**, 1, pp. 40—6, Cambridge, 1949.

Dunbar, M. J. "The Pinnipedia of the Arctic and sub-Arctic". Fish. Res. Board Canada, Bull. 85, Ottawa, 1949.

Gunther, E. R. "The habits of fin whales". Discovery Rep., **25**, pp. 113—42, Cambridge, 1949.

Karcher, F. H. "Die untere Grenze des Fettgehaltes beim Finnwal". Arch. f. Fisch. Wiss., 1 Jahrg., 1—2, pp. 3—8, Hamburg, 1948.

Scattergood, L. W. "Notes on the little piked whale". Murrelet, **30**, 1, U. S. A., 1949.

9) Freshwater Fisheries and Fishery Investigations.

9)a Salmonidae.

Anon. "Annual report, 1948". Internat. Pacific Salmon Fish. Comm., New Westminster, Canada, 1949.

Brett, J. R. "The design and operation of a trap for the capture of migrating young sock-eye salmon". Trans. American Fish. Soc., **75**, pp. 99—104, New York, 1948.

Chapman, D. G. "A mathematical study of confidence limits of salmon populations calculated from sample tag ratios". Bull. Internat. Pacific Salmon Fish. Comm., 11, pp. 67—85, New Westminster, B. C., 1948.

Daniel, R. J. "The distribution of ascorbic acid in developing salmon (*Salmo salar* L.)". Biochem. Journ., **45**, 4, pp. 435—8, Cambridge, 1949.

Denzer, H. W. "Untersuchungen über die Körpertemperatur der Regenbogenforelle. 1. Die Methode an der Temperaturmessung der Leibeshöhle, des Darmes und des Herzbeutels erläutert". Arch. f. Fisch. Wiss., 1 Jahrg., 3—4, pp. 101—11, Hamburg, 1948.

Elster, H. J. "Untersuchungen über die Bodensee-Blaufelchenfischerei im Jahre 1943 und über die Auswirkungen der kriegsbedingten Fangeinschränkung". Arch. f. Fisch. Wiss., 1 Jahrg., 3—4, pp. 142—63, Hamburg, 1948.

Foster, R. F. *et al.* "The effect on embryos and young of rainbow trout from exposing the parent fish to X-rays". Growth, **13**, pp. 119—42, U. S. A., 1949.

Fry, F. E. J. "Statistics of a lake trout fishery". Biometrics, **5**, 1, pp. 27—67, U. S. A., 1949.

Howard, G. V. "A study of the tagging method in the enumeration of sock-eye salmon population". Bull. Internat. Pacific Salmon Fish. Comm., 11, pp. 7—66, New New Westminister, B. C., 1948.

Jones, J. W. "Studies of the scales of young salmon, *Salmo salar* L. (juv.)". Min. Agric. and Fish., Fish. Invest., Ser. 1, **5**, 1, London, 1949.

Meyer, P.-F. "Massnahmen zur Hebung des Salmonidenbestandes in der Ostsee". Allg. Fisch. Zeit., Jahrg. 1942, 11—12, Augsburg, 1942.

Neave, F. "Game fish populations of the Cowichan river". Fish. Res. Board Canada. Bull. 84, Ottawa, 1949.

Quirll, F. "Sind die im Herbst laichenden Regenbogenforellen Standfische?". Arch. f. Fisch. Wiss., 1 Jahrg., 3—4, pp. 112—35, Hamburg, 1948.

Phillips, A. M., Brockway, D. R., and Rodgers, E. O. "Use of cod-liver oil in the diet of hatchery-reared trout". Progressive Fish-Culturist, **11**, 2, pp. 109—12, Washington, 1949.

Pritchard, A. L. "Efficiency of natural propagation of the pink salmon (*Oncorhynchus gorbuscha*) in McClinton creek, Masset inlet, B. C.". Journ. Fish. Res. Board Canada, **7**, 5, pp. 224—36, Toronto, 1948.

Rübenberg, L. "Markierungsversuche mit geangelten Junglachsen". Monatsh. f. Fisch., 12 (Dezember), Cuxhaven, 1941.
Storrow, B. "Concerning salmon caught in the fishery district of the River Tyne". Rep. Dove Mar. Lab. Cullercoats, Ser. 3, 10, pp. 7—54, Newcastle-upon-Tyne, 1949.
Went, A. E. J. "Sea trout of the Owengowla (Gowla river)". Sci. Proc. Roy. Dublin Soc., N. S., **25**, 5, pp. 55—64, Dublin, 1949.
Winge, Ö., and Ditlevsen, E. "A study on artifical hybrids between salmon (*Salmo salar*) and brown trout (*Salmo trutta*)". C. R. Travaux Lab. Carlsberg, Sér. Physiol., **24**, 23, Copenhagen, 1948.

9) b Eels.

Meyer, P.-F. "Die Bedeutung des Aales für die Ostseefischerei". Monatsh. f. Fisch., 3 (März), Cuxhaven, 1942.

9) c Other Commercial Species.

Berzins, B. "On the biology of the Latvian perch (*Perca fluviatilis* L.)". Hydrobiologia, **2**, 1, pp. 64—71, den Haag, 1949.
Mann, H. "Über die Rohfaser-Verdauung des Karpfens". Arch. f. Fisch. Wiss., 1 Jahrg., 1—2, pp. 68—78, Hamburg, 1948.

9) d Effects of Pollution.

Nolte, E., und Bandt, H. "Biologische Abwasserreinigung mit belebtem Schlamm in Gegenwart von Cyam". Beitr. Wasser-, Abwasser- u. Fischereichemie, pp. 9—14, Magdeburg, 1946.
Tully, J. P. "Oceanography and production of pulp mill pollution in Alberni inlet". Fish. Res. Board Canada, Bull. 83, Ottawa, 1949.

9) e Ecology.

Anon. "Interim report on the Chilko River Watershed". Internat. Pacific Salmon Fish. Comm., New Westminister, B. C., 1949.
Boettger, C. R. "*Basommatophora*". Tierwelt d. Nord- u. Ostsee (Grimpe u. Wagler), **35**, 9b2, Leipzig, 1944.
Bourrelly, P. "Activités algologiques et limnologiques en France pendant les années 1947—1948". Hydrobiologia, **2**, 1, pp. 72—83, den Haag, 1949.
Jørgensen, E. G. "Diatom communities in some Danish lakes and ponds". Kgl. Danske Vidensk. Selsk., Biol. Skr., **5**, 2, Copenhagen, 1949.
Lenz, F. "Die Edelmaräne in den Plöner Seen". Arch. f. Fisch. Wiss., 1 Jahrg., 3—4, pp. 163—73, Hamburg, 1948.
Lynch, J. J. *et al.* "Effects of aquatic weed infestations on the fish and wildlife of the Gulf States". U. S. Dept. Interior, Fish and Wildlife Serv., Spec. Sci. Rep. 39, Washington, 1947.
Schäperclaus, W. "Düngungsversuche in einem märkischen See". Arch. f. Fisch. Wiss., 1 Jahrg., 3—4, pp. 136—42, Hamburg, 1948.
Speirs, J. M. "Summary of literature on aquatic weed control". Canadian Fish Culturist, **3**, 4, pp. 20—32, Toronto, 1949.

10) Shellfisheries.

10) a Molluscs.

Adams, J. R. "The oyster drill in Canada". Progress Rep. Atlantic Coast Stat., 37, pp. 14—7, St. Andrews, 1949.
Kerswill, C. J. "Effects of water circulation on the growth of quahugs and oysters". Journ. Fish. Res. Board Canada, **7**, 9, pp. 545—51, Toronto, 1949.

10) b Crustacea.

Graham, M. "A note on the theory of a dwarf race of lobsters on the Norfolk coast". Journ. Mar. Biol. Assoc. U. K., N. S., **28**, 2, pp. 481—7, Cambridge, 1949.
Southall, C. L., and Rensburg, N. J. van. "Distribution of chitin in crawfish". Fishing Industry Res. Inst., Progress Rep. 6, Cape Town, 1949.
Templeman, W., and Tibbo, S. N. "Lobster investigations in Newfoundland, 1938 to 1941". Dept. Nation. Resources, Res. Bull. 16, St. John's, Newfoundland, 1945.

Templeman, W. "Abnormalities in lobsters". Bull. Newfoundl. Governm. Lab., 18, pp. 3—8, St. John's, Newfoundland, 1948.
Templeman, W. "Body form and stage identification in the early stages of the American lobster". Bull. Newfoundl. Governm. Lab., 18, pp. 12—25, St. John's, Newfoundland, 1948.
Templeman, W. "Growth per moult in the American lobster". Bull. Newfoundl. Governm. Lab., 18, pp. 26—48, St. John's, Newfoundland, 1948.
Wilder, D. G. "The effect of fishing on lobster populations as determined by tagging experiments". Progress Rep. Atlantic Coast Stat., 37, pp. 10—3, St. Andrews, 1949.

11) Miscellaneous.

11) a General.

Anon. "Five technical reports on food and agriculture". Food and Agric. Organization of the United Nations, 1945.
Anon. "Références sur 1. La défense des côtes et des berges contre l'érosion. 2. Dunes, ripples, etc. Formes des matériaux pulvérulents sous l'action d'un courant fluide. 3. Hydrodynamique des marées. 4. Hydrodynamique des vagues". Ateliers Neyret-Beylier and Piccard-Pictet, Grenoble, 1945.
Anon. "Narada rybacka Szczecin, 27—28 wrzesnia 1946 roku". Morsk. Inst. Ryb. Gdyni, Gdynia, 1947.
Anon. "Bibliographia Oceanographica". **16**, Rome, 1949.
Anon. "International northwest Atlantic fisheries conference, final act and convention". H. M. S. O., Miscellaneous, 4, Cmd. 7658, London, 1949.
Anon. "Procès-Verbaux (Octobre-1948) et Rapport Administratif (1947)". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **124**, Copenhague, 1949.
Bergmann, W. "Comparative biochemical studies on the lipids of marine invertebrates, with special reference to the sterols". Journ. Mar. Res., **8**, 2, pp. 137—76, New Haven, Conn., 1949.
Danois, E. le. "Les profondeurs de la mer: 30 ans de dragages". Payot, Paris, 1949.
Gall, J. le. "Le problème mondial actuel des pêches maritimes". Office Sci. et Tech. Marit., Notes et Rapports (N. S.), 4, Paris, 1949.
Macginitie, G. E., and N. "Natural history of marine animals". McGraw Hill Book Co., Inc., New York, 1949.
Moore, H. B. "A camera for producing one-dimensional reduction in narrow records". Journ. Mar. Res., **8**, 1, pp. 21—3, New Haven, Conn., 1949.
Solomon, M. E. "The natural control of animal populations". Journ. Animal Ecology, **18**, 1, pp. 1—35, Cambridge, 1949.
Speirs, J. M. "Bibliography of Canadian biological publications for 1946". Dept. Lands and Forests, Div. Res., Biol. Bull., No. 3, Ontario, 1949.
Stubblefield, A. G., Lefervre, L., and Smart, R. "Montana fish-distribution tank". Progressive Fish-Culturist, **11**, 4, pp. 245—52, Washington, 1949.
Thore, S. "Investigations on the 'Dana' octopoda". Carlsberg Found. Oceanogr. Exped. round the world 1928—30, Dana Report, 33, Copenhagen and London, 1949.
Tunison, A. V., Mullin, S. M., and Meerhean, O. L. "Survey of fish culture in the United States". Progressive Fish-Culturist, **11**, 1, pp. 31—69, Washington, 1949.

11) b Mathematical and Statistical Methods.

Weibull, W. "A statistical analysis of the size of Cyrtoidea in 'Albatross' cores from the east Pacific Ocean". Nature, **164**, 4181, pp. 1047—8, London, 1949.

Index to Volume XVI.

Articles.

Bogucki, M. and **Trzesinski, P.** Fluctuations in the Water and Fat Content of the Cod 208
Bruun, Anton Fr. The Use of Nematodes as Food for Larval Fish 96
Cable, Louella E. A Cheek Tag for Marking Fish, with Semi-Automatic Pliers for Application of Tag 185
Chrzan, F. Investigations on the Baltic Cod 192
Dannevig, Alf and **Dannevig, Gunnar.** Factors affecting the Survival of Fish Larvae 211
Desbrosses, Pierre. Dimorphisme Sexuel chez quelques Téléostéens de la Côte Atlantique Française 63
Fontaine, M. et **Vibert, R.** Sur un Parr de Saumon Hermaphrodite parvenue à Maturité Sexuelle 216
Forest, Jaques. Observations sur deux Ammodytidés des Côtes Françaises, *Ammodytes lanceolatus* Lesauvage et *Ammodytes lancea* Cuvier 179
Frost, Winifred E. The Eel Fisheries of the River Bann, Northern Ireland, and Observations on the Age of the Silver Eels 358
Furnestin, Jean et **Coupe, René.** Les Caractéristiques Morphologiques des Anchois (*Engraulis encrasicholus* Linn.) du Maroc 182
Føyn, Ernst. Ammonia Determination in Sea Water 175
Haller Nielsen, Per. An Auxiliary Apparatus for Plankton Studies by means of the Sedimentation Method 307
Hart, T. J. A Note on Growth Zones in Bones of *Phycis blennoides* Brünn 335
† **Jacobsen, J. P.** Some Characteristic Features in the Variation of Surface Temperature in the North Atlantic 17
Jurva, Risto. On the Cartographical Method for Studies of the Ice off the Finnish Coast 294
Järvi, T. H. A Review of the Results of Salmon Marking in the Baltic Region 100
King, J. Some Notes on the Determination of the Chlorinity of Sea Water by Comparison with the International Standard 167
Letaconnoux, R. Quelques Cas Tératologiques chez les Poissons 50
Letaconnoux, R. Note sur les Caractères Sexuels Secondaires du *Callionymus lyra* 59
Menon, M. D. The Use of Bones, other than Otoliths, in Determining the Age and Growth-Rate of Fishes 311
Nordli, Ottar. Precipitate in Sea-Water Samples for the Study of Plankton 310
Parrish, B. B. Haddock Stocks in the North Sea during 1946 74

Theisen, E. Methods for Rapid Temperature Determination from Thermograms along a Ship's Course 44
Vedel Tåning, Å. On the Breeding Places and Abundance af the Red Fish (*Sebastes*) in the North Atlantic 85
Went, Arthur E. J. Salmon of the River Shannon in 1946 and 1947 341

Essay Review.

Kesteven, G. L. "A Symposium on Fish Populations held at the Royal Ontario Museum of Zoology, Toronto, Canada, January 10th and 11th, 1947." 227

Reviews.

Armstrong, E. F. and **Miall, L. M.** Raw Materials from the Sea. (H. Barnes) 113
Bell, R. P. The Use of the Terms "Acid" and "Base". (L. H. N. Cooper) 385
Bigelow, H. B. and **Edmondson, W. T.** Wind Waves at Sea, Breakers and Surf. (N. F. Barber) 242
Bigelow, H. B.; Farfante, I. P.; Schroeder, W. C. Fishes of the Western North Atlantic. (Anton Fr. Bruun) 397
Bogorov, B. G. Peculiarities of Diurnal Vertical Migration of Zooplankton in Polar Seas. (F. S. Russell) 393
von Brand, T., Rakestraw, N. W. and **Renn, C. E.** Further experiments on the decomposition and regeneration of nitrogenous organic matter in sea water. (H. Barnes) 113
von Brand, T. and **Rakestraw, N. W.** Decomposition and regeneration of nitrogenous organic matter in sea water. III. Influence of temperature and source and condition of water. IV. Inter-relationship of various stages; influence of concentration and nature of particulate matter. — — — — and **Zabor, J. W. V.** Factors influencing the length of the cycle; observations upon the gaseous and dissolved organic nitrogen. (H. Barnes) 114
Cooper, L. H. N. Phosphate and Fisheries. (T. Braarud) 247
Corbin, P. G. The spawning of mackerel, *Scomber scombrus* L. and pilchard *Clupea pilchardus* Walbaum, in the Celtic Sea in 1937 and 1939, with observations on the zooplankton indicator species, *Sagitta* and *Muggiaea.* (P. Desbrosses) 249
Dunbar, J. M. The State of the West Greenland Current up to 1944. (H. Thomsen) 388
Einarsson, H. Euphausiacea. I. Northern Atlantic Species. (I. Gordon) 243
Fage, L. Mysidacea: Lophogastrida — I. — II. (I. Gordon) 244
Fraser, J. H. The Distribution of Thaliacea (Salps and Doliolids) in Scottish Waters 1920 to 1939. (J. G. Cattley) 394
Jespersen, Poul. Indo-Pacific Leptocephalids of the genus *Anguilla.* Systematic and biological studies. (E. Trewavas) 254
Jones, N. S. Observations and experiments on the biology of *Patella vulgata* at Port St. Mary, Isle of Man. (R. Letaconnoux) 245
Lodge, Sheila M. Algal growth in the absence of *Patella* on an experimental strib of foreshore, Port St. Mary, Isle of Man. (R. Letaconnoux) 245
Lucas, C. E. and **Rae, K. M.** The plankton of the North Sea in relation to its environment. Part I, the hydrological background in the southern North Sea, 1930—1937. (P. Groen) 239
McKenzie, R. A. The Canadian Atlantic Halibut Fishery. (Finn Devold) 248

Marcotte, A. et **Tremblay, J.-L.** Notes sur la Biologie de l'Éperlan (*Osmerus mordax*, Mitchill) de la province de Québec. (M. Bogucki) 253
Marshall, S. M. and **Orr, A. P.** Further experiments on the fertilization of a sea loch (Loch Craiglin). The effect of different plant nutrients on the phytoplankton. (T. Braarud) 246
Moore, Hilary B. The zooplankton of the upper waters of the Bermuda area of the North Atlantic. (P. Jespersen) 396
Mosby, Håkon. The Thermo Sound: an Oceanographic Temperature Recorder. (A. J. Lee) 241
† **Paulsen, O.** Observations on Dinoflagellates (Edited by J. Gronved). (F. Bernard) 389
Rakestraw, N. W. and **von Brand, T.** Decomposition and regeneration of nitrogenous organic matter in sea water. (H. Barnes) 113
Rakestraw, N. W. and **von Brand, T.** Decomposition and regeneration of nitrogenous organic matter in sea water. VI. The effect of enzyme poisons. (H. Barnes) 114
Rakestraw, N. W. The Conception of Alkalinity or Excess Base of Sea Water. (L. H. N. Cooper) 385
Reid, Robert O. The Equatorial Currents of the Eastern Pacific as Maintained by the Stress of the Wind. (H. Mosby) 389
Riley, G. A. Factors controlling Phytoplankton Populations on Georges Bank. — A Theoretical Analysis of the Zooplankton Population of Georges Bank. — Seasonal Fluctuations of the Phytoplankton Population in New England Coastal Waters. (L. Fage) 117
Riley, G. A. Plankton Studies. IV. Georges Bank. (T. Braarud) 392
Riley, G. A. The relationship of vertical turbulence and spring diatom flowerings. (T. Braarud) 393
Riley, G. A. and **Bumpus, D. F.** Phytoplankton-Zooplankton Relationships on Georges Bank. (L. Fage) 117
Sears, Mary. Note on the phytoplankton on Georges Bank in 1940. (T. Braarud) 391
Soleim, P. A. Årsaker til rike og fattige årganger af sild. (E. M. Poulsen) 240
Steven, G. A. Contributions to the Biology of the Mackerel, *Scomber scombrus* L.: Mackerel Migrations in the English Channel and Celtic Sea. (P. Desbrosses) 251
Stockman, W. B. A Theory of T-S Curves as a Method for Studying the Mixing of Water Masses in the Sea. (H. Mosby) 388
Stommel, H. Note on the Use of the T-S Correlation for Dynamic Height Anomaly Computations. (H. Mosby) 388
Sverdrup, H. U., Johnson, M. W. and **Fleming, R. H.** The Oceans: their Physics, Chemistry, and General Biology. (G. E. R. Deacon) ... 237
Wiborg, K. F. The Production of Zooplankton in the Oslo Fjord in 1933—1934, with special reference to the Copepods. (G. P. Farran †) 116
Wilson, D. P. The triradiate and other forms of *Nitzschia closterium* (Ehrenberg) Wm. Smith, forma *minutissima* of Allen and Nelson. (T. Braarud) 390
Wimpenny, R. S. The size of diatoms. II. Further observations on *Rhizosolenia styliformis* (Brightwell). (T. Braarud) 390

Notices and Correspondence.

Obituary Notices:—
Farran, George Philip (1876—1949) by Arthur E. J. Went 160
Hjort, Johan (1869—1948) by K. A. Andersson 3
Knudsen, Martin (1871—1949) by Helge Thomsen 155
Liebert, François (1882—1948) by J. J. Tesch 164

Paulsen, Ove (1874—1947) by E. Steemann Nielsen 14
Thompson, D'Arcy Wentworth (1860—1948) by R. S. Clark 9

Editorial Notes:—
The Gold Medal of the Zoological Society of London awarded to Mr. Henry G. Maurice, Président d'Honneur of the International Council 16
The *Zooplankton Identification Sheets*, a new series published by the International Council 16
Change in the directorship of the Woods Hole Oceanographic Institution 384

Current Bibliography.

Current Bibliography prepared by the Editor with the assistance of A. C. Simpson ..... 119, 258 and 399

Recent Publications of the International Council:

RAPPORTS ET PROCÈS-VERBAUX.

Vol. No. 125: Contributions to Special Scientific Meetings 1948. I. Climatic Changes in the Arctic in relation to Plants and Animals. II. The Comparative Efficiency of Fishing Craft, their Gear and Modification of Gear. Décembre 1949. Kr. 10.00.

Vol. No. 126: Rapport Atlantique. Réunion des Experts du Conseil International pour l'Exploration de la Mer à Biarritz, 20—26 Avril 1948. Biologie des Clupéidés (le Hareng excepté). In the press.

Vol. No. 127: Procès-Verbaux (Oct. — 1949). Rapport Administratif (1948). Mai 1950. Kr. 12.00.

ANNALES BIOLOGIQUES.

Vol. No. V: 1948. Décembre 1949. Kr. 18.00.

BULLETIN HYDROGRAPHIQUE pour les années 1938 et 1939. Juillet 1944. Kr. 10.00.
pour les années 1940—1946 avec Appendice: Atlantique — Florida 1936—1939. In the press.

BULLETIN STATISTIQUE pour les années 1940—1944. Août 1949. Kr. 10.00.

FICHES D'IDENTIFICATION DU ZOOPLANCTON. First Instalment, Nos. 1—17. Mai 1949. Kr. 10.00.
Second Instalment, Nos. 18—29, in preparation.

INDEX TO PUBLICATIONS by the International Council for the Exploration of the Sea, 1899—1938, in loose-leaf binding. Janvier 1939. Kr. 5.00.

Table of Contents.

Page

1. **Risto Jurva.** On the Cartographical Method for Studies of the Ice off the Finnish Coast 293
2. **P. Haller Nielsen.** An Auxiliary Apparatus for Plankton Studies by means of the Sedimentation Method. 307
3. **Ottar Nordli.** Precipitate in the Sea-Water Samples for a Study of Plankton 310
4. **M. D. Menon.** The Use of Bones, other than Otoliths, in Determining the Age and Growth-Rate of Fishes 311
5. **T. J. Hart.** Appendix. A Note on Growth Zones in Bones of *Phycis blennoides* Brünn 335
6. **A. E. J. Went.** Salmon of the River Shannon in 1946 and 1947. . . . 341
7. **Winifred E. Frost.** The Eel Fisheries of the River Bann, Northern Ireland, and Observations on the Age of the Silver Eels 358
8. Editorial Note 384
9. Reviews 385
10. Current Bibliography prepared by the Editor with the Assistance of Mr. A. C. Simpson 399
11. Index to Volume XVI 416

A/S L. IHRICH . COPENHAGEN